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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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Patents and Designs Acts, 1907 and 1919.

Notice is Hereby Given that Henry Clarke of 4, Millway, Mill Hill, London, N.W. Seeks Leave to amend the Specification of Letters Patent No. 133457, granted to him for "Improvements in Extincteurs."

Particulars of the proposed amendment were set forth in the Illustrated Official Journal (Patents), issued on the 8th December, 1920.

Any person or persons, may give notice of Opposition to the Amendment by leaving Patents Form No. 19 at the Patents Office, 25, Southampton Buildings, London, W.C. 2, within one calendar month from the date of the said Journal.

W. Temple Franks,
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Two copies of the Form of Tender, Contract Agreement, Specification, and Bills of Quantities may be obtained by sending in an application, with a deposit of £6 Sterling, to Messrs. Sir Alex. Binnie, Son & Deacon, and such deposit will be refunded when a *bona fide* Tender, accompanied by the Specification, &c., has been received by the Chairman of the Jharia Water Board. The Board does not bind itself to accept the lowest or any Tender.

E. S. Hoernle,
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Address, giving age, full experience and salary required, L 297, Offices of Engineering.

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Candidates must preferably have passed the Associate Membership Examination of the Institution of Civil Engineers, or have taken a degree exempting from such examinations; they must also have had considerable experience in design, construction and maintenance on railways in Great Britain or in Foreign Countries.

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Applicants must give a full chronological record of their general and technical education, apprenticeship or pupilage and subsequent engineering experience. Those who may have served in the late War should give particulars and date of that service. Candidates must also state whether they are married or single. L 299

Applications, accompanied by copies of any testimonials, must be addressed to the Company's Consulting Engineer, ROBERT WHITE, Esq., M.Inst.C.E., 3, Victoria Street, London, S.W. 1.

COLOMBO MUNICIPAL COUNCIL, CEYLON.

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The Colombo Municipal Council requires the

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Applicants should have passed the examination of Associate Member of the Institute of Civil Engineers or hold some other equivalent qualification.

Candidates should be unmarried and be between 25 to 33 years of age.

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N. M. Ingram, Esq.,
Burlingham Rectory,
Burlingham,
Norfolk,

and must be received not later that 15th January, 1921.

By Order,
B. H. Joseph,
Secretary, Municipal Council, Colombo.
The Town Hall,
Colombo, 12th November, 1920. L 194

Draughtsman Wanted. Previous experience on Boilers and Structural work a necessary qualification. Good opening for experienced man.—Address, stating salary required, age and references, L 245, Offices of Engineering.

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Foreman-Engineer Wanted for large Works in Kent. Must be experienced in up-keep of heavy mill machinery, steam engines, gas engines, locomotives, and cranes.—Address, stating age, experience and wages required, L 269, Offices of Engineering.

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ARCH BRIDGES.

A REMARKABLE paper on steel arches has been contributed to the Proceedings of the American Society of Civil Engineers by Mr. J. A. L. Waddell, the well-known bridge engineer. Finding his ordinary professional work interrupted by the war he seized the opportunity to make a very elaborate study of the economics of steel arch bridges. The problem he set himself was to determine the proportions of rise to span, depth of rib and type of arch which required least steel in the superstructure. The plan of investigation followed was to get out complete detailed designs for each type with different ratios of span to rise and different depths of the rib. The weights were taken from these drawings, and by plotting these the most economical values of the variables concerned could be ascertained. The labour involved was, of course, immense, and Mr. Waddell well deserves the thanks of constructional engineers for the courage and determination with which he faced and completed the task.

For three-hinged arches with the grade line approximately tangent to the top chord of the arch at the crown, the most economical ratio of rise to span was found to be as follows :—

Solid rib structures	0·2
Braced rib structures...	0·225
Spandrel braced structures with hinge above	0·25

All these values may be decreased or diminished by 0·025 without material difference in the weights. For three hinged half-through arches, the best ratio of span to rise was found to be 0·225 for solid rib structures and 0·30 for braced ribs. Finally, for three hinged arches carrying a deck high above the rib, the best ratio of rise to span was found to be 0·25 to 0·28 for solid rib structures and 0·33 to 0·38 for braced ribs. These conclusions are based on designs for spans 200 ft., 500 ft. and 800 ft. long. It was further found that the most economic ratio of rise to span was practically unaltered if one of the hinges were eliminated, but with a hingeless arch, the ratio of rise to span should be increased to 0·28 for a low-deck structure, 0·33 for a "half-through" arch and to 0·38 for a high-decked bridge. As for the best depth of the arched rib, Mr. Waddell observes that in the case of solid ribs the depth should be the maximum consistent with proper resistance to the thrust. With braced ribs and three-hinged arches the best depth is 7·5 per cent. of the span length, but considerable departures from this do not greatly affect the weight. In the case of two hinged arches, Mr. Waddell finds that the crescent shape is only slightly more economical than a rib of uniform depth. In the case of hingeless arches he concludes that the depth at the springings should be twice that at the crown.

The following formulas for the weights of arched bridges were deduced from the numerous computations made : It l be the span in feet and W denote the weight of metal per linear foot of span in the arches alone, D the dead load in pounds per linear foot, and L the live load plus impact, also in pounds per linear foot, then :—

For three hinged arches

$$W_a = (0{\cdot}000282\ D + 0{\cdot}000426\ L)\ l$$

For two hinged arches :

$$W_a = (0{\cdot}000248\ D + 0{\cdot}000416\ L)\ l$$

For hingeless arches :

$$W_a = (0{\cdot}000272\ D + 0{\cdot}000460\ L)\ l$$

These figures are based upon a theory of the author's that in the case of "reversing" stresses one-half the sum of the smaller stress should be added to the larger and the member proportioned for the sum thus found. If the effect of "reversal" be ignored the formulas become :—

For three hinged arches :

$$W_a = (0{\cdot}000292\ D + 0{\cdot}000396\ L)\ l$$

For two hinged arches :

$$W_a = (0{\cdot}000258\ D + 0{\cdot}000380\ L)\ l$$

And for hingeless arches :

$$W_a = (0{\cdot}000270\ D + 0{\cdot}000398\ L)\ l$$

It is obvious from their form that the above equations must be considered as formulas of interpolation only and should not be used for spans far outside of the limits for which the calculations were made, that is to say, for spans outside of the limits of 200 ft. and 800 ft. covered by the calculations.

In his paper, Mr. Waddell does not give the impact factor adopted, a factor which, as frequently applied in American practice, is wholly unscientific and at variance with all observations on actual bridges made with the requisite care.

So far as the assumptions adopted in his calculations are acceptable, Mr. Waddell's results are no doubt to be relied on, and in any case must be of great service to constructional engineers. Of course, as he himself points out, considerable departures from the proportions giving the greatest economy of steel may be advisable in view of other considerations, but even fairly large departures do not generally involve any excessive increase in the total weights. As regards the comparison Mr. Waddell makes between hinged and rigid arches, however, a personal factor enters, and his conclusions will accordingly be disputed by many engineers. He concludes from his calculations that the hinged arch is considerably more economical than the rigid arch, a view which is contrary to that held by many other engineers. Mr. Waddell, however, arrives at his results owing to the importance he attaches to what he calls reversal of stress. The term, if we understand him correctly, however, is somewhat of a misnomer, as apparently in most cases the stress on the members under consideration is not actually reversed, but merely varies through a considerable range.

Undoubtedly, as James Thomson proved in 1848, the elastic range of a material subjected to varying stress is closely connected with its strength, and his conclusion was confirmed by Bauschinger some thirty years later. Speaking roughly, it seems that the range of stress permissible on a test piece subject to varying stresses is nearly constant, that is to say a bar is nearly equally safe if subjected to a stress which varies from 0 tons to 20 tons per square inch, or from − 10 to + 10 tons per square inch. This is, of course, not quite true, but is approximately so. Actual structures are, however, composite, and in that case we think experience is in favour of the view that the joints will be tried more heavily by a reversal of stress than by a mere variation of stress, the sign of which remains constant. At any rate, this is certainly true in the case of pin-connected structures. As regards riveted joints it must be admitted that ships endure well in spite of the large nominal stresses admitted in their design. Severe calls on the structural strength of a ship occur only, however, at infrequent intervals, and the structure has, moreover, like a plate girder the advantage of being highly "indeterminate."

Mr. Waddell, it may be said, rather weakened his argument as to the relative strength of hingeless and hinged arches, in replying to the discussion on his paper. In this he observed that the believers in the economy of the rigid arch had made no proper allowance for what he calls reversal of stress as described above. He also suggested that the same mistake was made by the advocates of continuous girders, which he appears to think would show no economy if due allowance were made for this "reversal of stress." It is obvious from this observation that Mr. Waddell's views are founded on *a priori* reasonings, since in service, which is the real test, the record of continuous girders has been remarkably satisfactory. M. Rabut, for instance, found that continuous girders on the Western of France Railway were in perfect condition after many decades of service, under a traffic much heavier than they were originally intended to carry. Their behaviour was, in short, so satisfactory, that in widening a bridge on this line the original design was adhered to in spite of the increase in rolling loads since the original date of design and erection. In fact, commonsense is not always unreliable even in matters of structural engineering, and common sense suggests that if a rigid arch did fail, it would become immediately a hinged one and still sustain its load. Something of this sort happened some twenty-five or thirty years ago to the cast-iron bridge at Rochester. A barge knocked a chunk out of the the rib near mid span, but as parts still abutted the load continued to be carried, the arch then acting as if it had a hinge at the crown. Again, whilst it is quite true that the calculated stress on a T-beam may, if the table of the T be sufficiently thick and the stem sufficiently thin, be greater than if the stem were completely removed, no man with shop experience of the properties of mild steel, actually believes that the strength of the beam would be increased by this removal. In short, there is no reliable *a priori* method of fixing working stresses. Some American engineers seem loath to admit this. Thus a few years back experiments on chain links made in an American engineering laboratory indicated that in working conditions the calculated stress was of the order of 30,000 lb. per square inch. The experimenters accordingly declared that the recognised working loads for chains were too high and should be reduced. This, of course, was an utterly irrational conclusion. The real criterion as to whether a chain be strong enough is its behaviour in service, and this is notoriously satisfactory in spite of the abuse chains almost invariably receive.

For the same reason, Mr. Waddell's criticisms of rigid arches and of structures with redundant members generally, approach the problem, it seems to us, from the wrong angle. It is impossible to fix the true factor of safety of a structure merely by calculation unchecked by comparison with the behaviour of such structures in service.

Moreover, whilst a varying stress is undoubtedly more dangerous than a dead one, the number of repetitions of a stress is a factor not to be neglected. In guns the range of stress is exceedingly high, but it would be impossible to wear out a gun by fatigue, since before the requisite number of repetitions of stress had been attained the gun would already have been discarded for other reasons. Again, one of Wohler's iron bars broke only after 800 repetitions of a stress amounting to 22·92 tons per square inch. Had this varying stress been produced by seasonal changes, from summer to winter, some hundreds of years would have been needed to produce rupture. For this reason we are inclined to think that the importance of temperature stresses in rigid arches may well be over-estimated.

At any rate there is no question as to the satisfactory behaviour of redundant structures in service. Although there are, one or two instances on record of parts of such structures, when badly designed, breaking through temperature changes, these fractures have never involved the collapse of the bridge. The extraordinary endurance of such structures is well illustrated by the failure of the retreating Roumanians to destroy the great bridge over the Danube at Cernavoda in 1916. Here complete members were blown in two, yet the bridge stood and was easily and rapidly repaired. In fact, the record of redundant structures in service is exceptionally satisfactory, but nevertheless Mr. Waddell apparently still maintains that they are objectionable, and warmly repudiated a suggestion made in the discussion that he was swinging over to an approval of such structures. One American bridge engineer some decades ago, took up the unscientific attitude that the plate girder was the most unscientific of structures because it was impossible to calculate with accuracy the stresses to which it was subjected. It is not, however, scientific to regard a structure solely from the standpoint of the computer. Rankine pointed this out years ago in the inaugural dissertation he delivered on his appointment as Professor of Engineering at Glasgow. Macaulay had suggested that the barbarians that raised Stonehenge were destitute of scientific knowledge, because they were unacquainted with the parallelogram of forces, although they had the practical ability to pile up that enduring monument. Rankine claimed, however, that this practical knowledge was as much a branch of science as was the computation of stresses, and that to ignore it would be essentially unscientific.

A 5000-FT. HEAD HYDRO-ELECTRIC PLANT.

ALTHOUGH no great amount of hydro-electric development has been carried out in this country, this position of affairs is due more to low fuel costs in the past than to absence of natural facilities for such work. The potential water powers of Great Britain do not, of course, compare favourably with

those of say Norway, Sweden and France, but our position is better than is frequently supposed. It has been estimated that the horse-power available per square mile in Great Britain is 8·3, as compared with corresponding figures for Canada, the United States and Germany of 9·4, 9·3 and 6·8. Probably a considerable part of our potential water power is not commercially available, but there are certainly many sites offering favourable prospects, as recent investigations have shown, and developments in this direction would on general grounds appear to offer more attractive commercial prospects than schemes for the utilisation of tidal power.

The figures quoted above show this country in quite a favourable position as compared with the two great countries of the North American Continent, but a statement in terms of population would wear a different aspect. Owing to the relatively small size of these islands our total power available is, of course, enormously smaller than that of, say, the United States. Our small number of square miles means that we have no large watersheds, so that the total volume of water available is small. As, however, we have a hilly country, fair heads should be obtained in a number of cases, so that particularly for the smaller installations one may ultimately expect to see the Pelton wheel employed to a considerable extent here. From this point of view, and also from that of its intrinsic technical importance, the hydro-electric installation at Fully, in Switzerland, is of much interest.

THE HYDRO-ELECTRIC POWER STATION AT FULLY.

The installation is situated some few kilometres from Martigny, in the Rhone Valley, and operated from an Alpine lake situated 2,150 m. (7,000 ft.) above sea-level. The Pelton wheels are fed by a pipe line about 4·6 km. (2·85 miles) in length, which is connected to a tunnel 500 m. (550 yards) long, which is partly under pressure. The net head is 1,650 m. (5,412 ft.), which is probably the highest working head in existence. The generating station contains four sets each of 3,000 h.p., which run at 500 r.p.m., the Pelton wheels each having a single jet which strikes the wheel horizontally at its lowest point. A general view of the site showing the power station and in which the position of the pipe line is indicated is given in Fig. 1 herewith, while an interior view of the station showing the four turbine sets is given in Fig. 2.

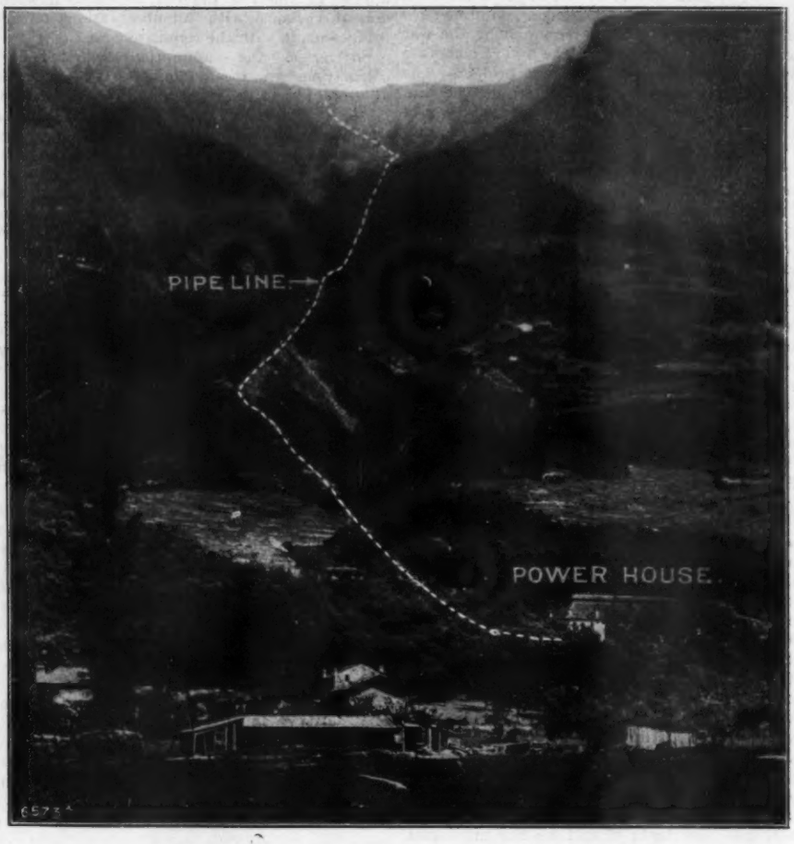


Fig. 1. General View of Power Plant and Site.

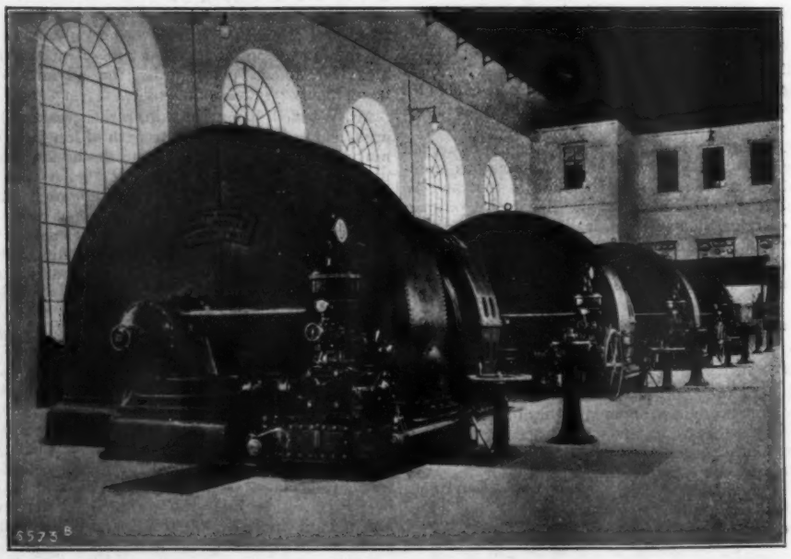


Fig. 2. Interior of Power House.

The Pelton wheels have an overall diameter of 3·715 m. (12 ft.) and are of forged steel. They each carry 54 buckets and are so designed that no part either of the disc or the buckets is subjected to a higher tension than 1,000 kg. per square centimetre (14,200 lb. per square inch) even in case of runaway. As each bucket is exposed more than eight times a second to the blow of the jet leaving the pipe at a velocity of about 180 m. per second (590 ft. per second) the method of fixing required careful study. The buckets have to resist the vibration produced by the continual blows and also the centrifugal stress of about 13 tons, which tends to force the bucket off the disc in the event of runaway. The bucket fixing arrangement which has been adopted is a patent of Messrs. Piccard Pictet, of Geneva, who built the wheels and carried out the whole of the hydraulic side of the installation. A view of one of the complete wheels is given in Fig. 3, on page 825, while Fig. 4 shows the method by which the buckets are secured. As will be seen the buckets are carried in a morticed groove, and are fixed tangentially by formed keys driven axially between them. The whole makes a very rigid assembly with the disc.

The wheel itself is fixed on the turbine shaft by means of a cone keyed to the shaft. This gives a true centering for the disc and allows of rapid dismantling if necessary. The end of the shaft on the alternator side is provided with a forged coupling disc, while the other end is direct coupled to the oil pump of the governor. The shaft is supported in two self-lubricated bearings mounted on a frame incorporated with the bedplate, which also carries the wheel case, the governor and the jet pipe. This cast-iron bedplate also forms a rectangular funnel below the wheel, which leads the outlet water from the turbine to a horizontal steel pipe of 1·30 m. (4·25 ft.) diameter and 10 m. (33 ft.) in length. This pipe issues from the power-house on the side opposite from the inflow of the water and empties into the tail race canal. At its outlet a sheet iron baffle holds up a certain depth of water and forms a deadening pool to break the velocity of the jet when deviated under the wheel by the deflection at times of sudden unloading. With a velocity of escaping water of about 180 m. a second, a tail race outlet of ordinary masonry would prove to be quite inadequate and would be rapidly worn away by the blows and eddies produced.

The water is conducted from the feed pipe to each turbine by a cast steel pipe of 250 mm. (10 in.) in diameter, provided with a manually-operated equilibrium valve. The jet pipe fixed to the bedplate under the turbine has a nozzle of tempered steel, the water discharge from which is regulated by a steel needle which moves in the axis of the jet pipe. The needle is always inclined to open

THE HYDRO-ELECTRIC POWER PLANT AT FULLY, SWITZERLAND.

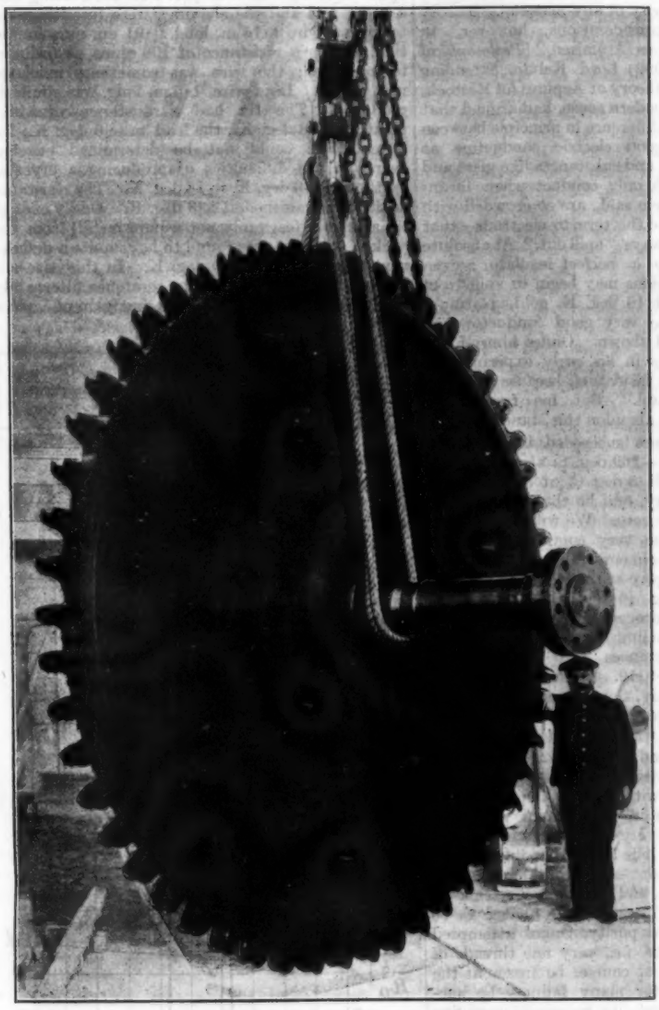


FIG. 3. DISC OF PELTON WHEEL.

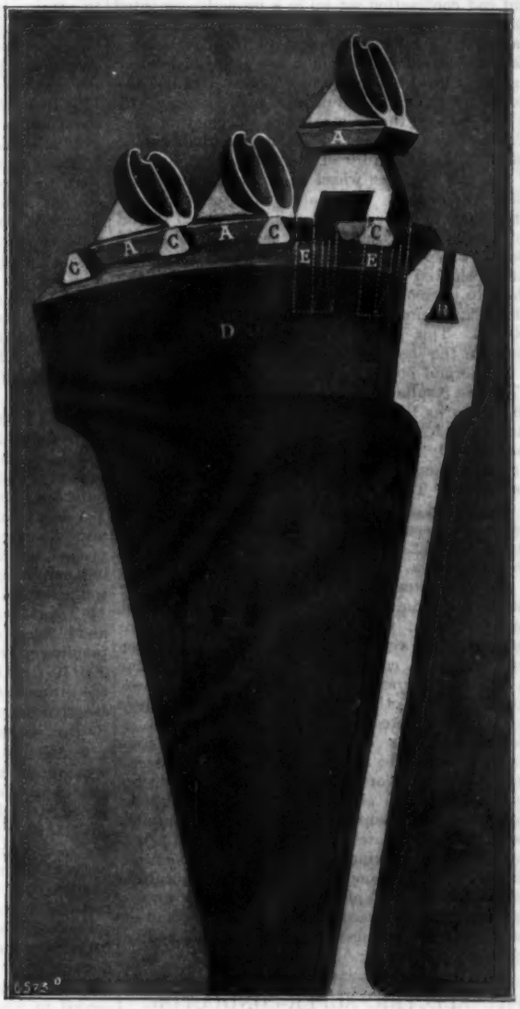
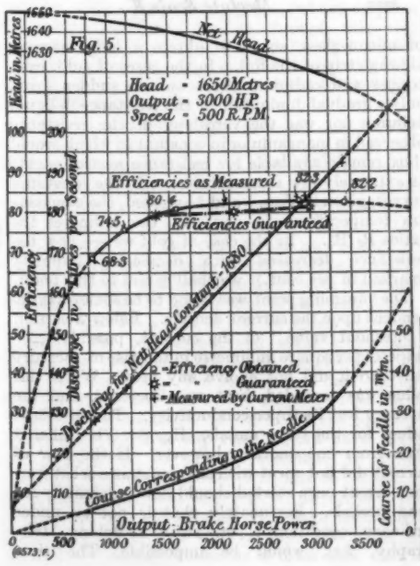


FIG. 4. METHOD OF FIXING BUCKETS.



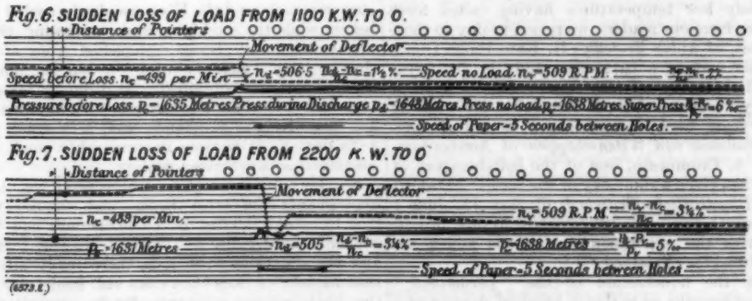


Fig. 6. SUDDEN LOSS OF LOAD FROM 1100 K.W. TO 0.
= Distance of Pointers
Movement of Deflector
Speed before Loss. n_e = 499 per Min.
n_d = 506·5
Speed no Load. n_r = 509 R.P.M.
Pressure before Loss. p_e = 1638 Metres Press during Discharge p_d = 1648 Metres Press. no load p_r = 1638 Metres Super Press
Speed of Paper - 5 Seconds between Holes.
Fig. 7. SUDDEN LOSS OF LOAD FROM 2200 K.W. TO 0
= Distance of Pointers
Movement of Deflector
n_e = 483 per Min.
n_r = 509 R.P.M.
p_e = 1631 Metres
n_d = 505
p_r = 1638 Metres
Speed of Paper - 5 Seconds between Holes
(6573.E.)

when affected by the water pressure. It can be closed by a hand-operated screw, by oil pressure-mechanism, or by the automatic governor. A cast-steel deflector placed between the nozzle and the bucket wheel is raised or lowered, by the action of the governor, and when lowered causes a deviation of the jet away from the buckets on the wheel. The first deflection of the jet is obtained on the side of the jet nearest to the bucket wheel by the fall of the deflector from above the jet. This has the effect of giving an exceedingly rapid deflection in case of sudden unloading of the the turbine. The governor is of the Piccard Pictet oil-pressure double-action type. During unloading, it acts first on the shape of the jet, suppressing at once the force which actuates the wheel, and secondly on the discharge of the jet by slowly reducing the quantity of water passing through the nozzle until discharge sufficient for the net load is obtained.

Various tests have been carried out in connection with this installation, both of efficiency and speed regulation of the machines. The efficiency was determined by electrical braking, the alternator current being absorbed by a liquid resistance fed by water from the tail-race canal. In calculating the power of the turbines it was assumed that the

very high figures of efficiency for the electrical machinery, furnished by the manufacturers, were exact. The electrical readings were taken on standard instruments, and the discharge of the turbines was measured by a weir with a thin wall and end contraction set up in a properly-cemented channel. The curve of the discharge of the weir was checked by measurement of the flow with a standard current meter which was calibrated before and after the tests. The test figures obtained are plotted in the curve given in Fig. 5, on page 825. It will be seen that a maximum efficiency of 82·3 per cent. was obtained, which is remarkably good considering the nature of the plant, and in view of the fact that the wheel as originally made and when these tests were taken was of abnormal dimensions in order that the runaway speed should not exceed more than 50 per cent. above normal speed. Some tests carried out by means of stop curves showed that the power absorbed by the wheel to overcome air friction only was very considerable, attaining at a speed of 500 r.p.m. nearly 150 h.p. This figure, which includes mechanical losses in the bearings, corresponds to 5 per cent. of the normal power.

The test results obtained on speed regulation tests are shown in Figs. 6 and 7. These are of much interest, and show that when a load of 3,200 h.p. was suddenly thrown off the turbine, the increase in speed was only 3½ per cent., as against 7 per cent. guaranteed. These percentages are in relation to the speed before unloading. The permanent variation in speed between no load and full load was 3½ per cent., this being the variation for which the governor was set. The super-pressure generated in the feed pipe during unloading was 0·6 per cent. as a maximum, corresponding to a generated head equivalent to 10 m. This very low figure compared with a specified over-pressure of 10 per cent., or about equivalent to a head of 160 m. As far as is known these results have not been equalled by any other station in the world. They are to be attributed to the double-action type of governor and its extreme sensibility. In conclusion, it should be said that with a view to introducing Messrs. Piccard Pictet's designs and utilising their experience in connection with hydro-electric projects in this country and the British Empire, Messrs. Vickers, Limited, of Broadway, Westminster, have come to a working arrangement with the firm. This association, combining the manufacturing resources of Messrs. Vickers with the expert knowledge of Messrs. Piccard Pictet, should become of considerable importance in the field of hydro-electric work.

THE ELECTRIC SUPER-CONDUCTING STATE OF METALS.

Recent references in our columns to the extraordinarily high electric conductivity of metals at extremely low temperatures having called forth inquiries from our readers, we revert to-day to these problems, of which Professor H. Kamerlingh Onnes has been making a particular study in the Cryogenic Laboratory of the University of Leiden. Lengthy accounts of these researches have during recent years been communicated to the *Koninglijke Akademie van Weienschappen* of Amsterdam, and C. A. Crommelin, one of the collaborators of Onnes, has given a summary of the results obtained in the *Physikalische Zeitschrift* of May 15, June 1 and June 15 last. We propose now to deal principally with the experimental methods which we have not so far explained.

When the liquefaction of the "permanent" gases had brought us within a hundred degrees and less of absolute zero of temperature (— 273 deg. C. or 0 deg. K. on the absolute scale also in deg. C), the fact was established that the increase in the electric resistance of metals with rising temperatures was continuous, or, if followed in the opposite direction, by a decided decrease in the resistance occurring at really low temperatures. It thus seemed reasonable to assume that the electric resistance would, if it did not actually vanish at absolute zero of temperature, at any rate approach zero value in an asymptotic manner. But the observed increase of conductivity with falling temperature was not always as regular as was expected. This was partly ascribed to the exceedingly great difficulties of the experimental determinations, and partly to the unavoidable presence of impurities.

We are, after all, as little likely really to attain to the absolute zero of temperature as we are to attain absolute purity of any material. Theory suggested further considerations, however. In his paper on "'Aepinus Atomised," (*Philosophical Magazine*, March, 1902) Lord Kelvin, extending the electron one-fluid theory of Aepinus (of Rostock, 1724 to 1802) in the modern sense, had argued that there need not be any difference in principle between metals, which are good electric conductors at ordinary temperature, and substances like glass and Nernst glowers, which only conduct when incandescent. Metals, Kelvin said, are so crowded with electrions—he preferred this term to electrons—that some electrions will always "spill out." At absolute zero a metal may be a perfect insulator; even at 1 deg. K. the electrions may begin to spill from atom to atom, and at 16 deg. K. gold, platinum and iron may become very good conductors, as Sir James Dewar had shown. Onnes himself was guided by these views in his early experiments; metals would become insulators, because the electrons were "frozen-up." But his further researches forced him to abandon this standpoint.

In July, 1908, Onnes succeeded in liquefying helium which boils at — 269 deg. C. at atmospheric pressure, and at — 271·5 deg. C. at a pressure of only 3 mm. of mercury, and he thus came within 1·5 deg. C. of absolute zero. We will not attempt any description of the very complex apparatus needed for these experiments. A platinum wire, 0·1 mm. in diameter, gave at the following absolute temperatures: 273 deg. (0 deg. C.); 20·2 deg.; 14·2 deg. (in liquid hydrogen); 4·3 deg.; 2·3 deg.; and 1·5 deg. (in liquid helium); the following corresponding relative resistances 1, 0·0171, 0·0135, 0·0119, 0·0119, and 0·0119. These figures express the ratios R_t/R_0, namely, the resistance at each respective temperature over the resistance at 0 deg. C. (Onnes, we may state, writes W instead of R).

There was thus found a decided approach to a constant value of the resistance, a result which was more compatible with the assumption of the presence of impurities in the drawn wire than with any reversal to a very high resistance according to Kelvin. Since it is hardly possible for any wires to be drawn without some contamination of the purity of the metal, and since mercury can, by distillation between 65 deg. C. and 70 deg. C. be produced in exceptional purity, Onnes attempted to prepare mercury wire, *i.e.*, very fine threads of mercury which would, of course, be frozen at the low temperatures. After many failures he succeeded in joining several (up to seven) very fine glass capillaries of V shape in such a way as to yield a continuous mercury thread. Each junction at the top of two U's was connected with the mercury reservoir, and the U's were slowly cooled from below, while the solidifying and contracting thread was continuously being replenished from above; thus a long "mercury wire" 0·105 sq. mm. in cross section, was obtained. At ordinary temperature this wire had a resistance of 173 ohms; at 4·2 deg. K. the resistance was very small; at 4·19 deg. K. it became immeasurably small, and continued so on further cooling.

So far as could be determined by these experiments the ratio R_t/R_0 was smaller than 2×10^{-10} at 2·45 deg. K. The mercury had thus suddenly passed into a "super-conducting" state, and the questions arose: Is there really any resistance left, *i.e.* does Ohm's law still hold?; or: Is the final, minute resistance due to impurities or to "bad spots" in general, irregularities or gaps in the fine wires, &c.? In the total absence of resistance, Ohm's law would be inapplicable, and, strictly speaking, our means of making electric measurements would be gone, since they are all based on Ohm's law. This fundamental question still remains unanswered, but there exists sufficient reason to distinguish this last trace of apparent resistance, remaining below the "vanishing point," from a very minute resistance in the ordinary sense by the term "microresidual resistance." How current measurements are actually made in liquid helium we will presently explain.

Similar measurements were made on other metals. Tin was fused in a vacuum and drawn into capillary glass tubes; or a steel core was covered with tin which was turned down on the lathe; a very fine spiral shaving was then pared off the coating with a razor tool and the shavings were fused togethre to form a wire 1·75 m. long, 0·01 sq. mm. in section, having a resistance of 190 ohms at ordinary temperature; the wire was sometimes insulated with picein. Lead wire, 1·5 m. long, was similarly produced. The tin had a resistance vanishing point at 3·78 deg. K., the lead near 6 deg. K.; the latter point could not be determined exactly, owing to the difficulties of producing a cryostat for the range 6 deg. K. to 14 deg. K. The resistance of thallium vanished at 2·3 deg. K. Oddly enough tin amalgam (certainly not a pure metal) from the back of a mirror, was found to have quite a definite vanishing point at 4·29 deg. K. In this case the wire was produced by making scratches, alternately from the right and left, on the amalgam of a piece

Fig. 1.

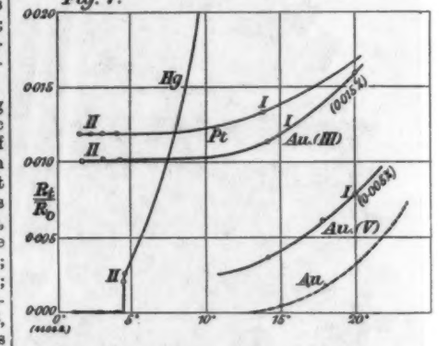
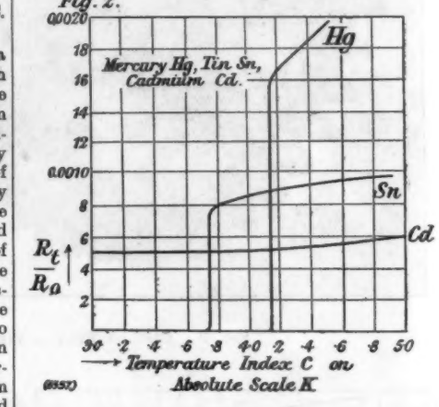


Fig. 2.



of mirror-glass, so as to obtain a long, narrow, zig-zag strip of the foil. In the cases of gold, iron, copper and cadmium there was no sudden drop, only a gradual diminution of the resistance in liquid helium; nor was the vanishing of the resistance observed in manganin or in constantan which would thus remain available for resistance measurements at extremely low temperatures. In the resistance curves, given in Figs. 1 and 2 annexed, the abscissae are temperatures in deg. K., the ordinates the ratios R_t/R_0. In the case of gold we see how the resistance decreased with decreasing impurity (marked in per cent.); we shall revert to this point.

The vanishing point was found to be somewhat dependent upon the current density. Below a certain "threshold value" of the current, possibly 1,200 amperes per square millimetre in the case of mercury the current did not evolve any heat. When this value was exceeded, heat was liberated, and the mercury lost its super-conductivity. The threshold values for the three metals, Hg, Sn, Pb, differed little from one another, however. If the flow of current did not meet with any resistance whatever, the current once started should flow indefinitely for long periods. Fortunately that is not so under ordinary conditions; otherwise switching, telegraphy, &c., would be impossible. The time

interval between the breaking of the circuit and the dying out of the current depends upon the ratio of self-induction to resistance, L/R, and is generally exceedingly short. One of Onnes' lead coils had a cross section of $\frac{1}{10}$ sq. mm. Wound on a brass tube, 8 cm. in diameter, the wire had at 15 deg. C., a resistance of 734 ohms, and a self-induction of 10 millihenry; the relaxation period (in which the interrupted current would decay to 1/e of its value, somewhat as in radioactivity) was hence 1/70,000 second. At 1·8 deg. K. the current should have flowed for days. Observation for so long a period was impossible, because even with very prolonged preparations, liquid helium experiments leave at the best but a few hours for actual measurements. The determinations were made in the way we shall now proceed to describe.

The coil was suspended in helium (inside a double vacuum-jacketed vessel) between the poles of an electro-magnet giving a field of 400 gauss; the field was reduced to 200 gauss in 10 seconds and then removed, which took three seconds. The current thus induced deflected a magnetic needle in the outer circuit indicating a current of about 0.6 ampere which flowed for hours. By modifying the experiment in various ways the current diminution was found to amount to about 1 per cent. per hour, and at that rate the current would have taken four days to vanish. We know nothing about any possible magnetism of brass, even if free from iron, at these temperatures; but no magnetic phenomena were observed in special experiments.

To make sure that the current was really due to electro-magnetic induction, the ends of the lead coil were fused together to form a loop by which the coil was suspended from the hook of a long rod, protruding outside the apparatus. By pulling the hook up the lead wire was suddenly broken in the loop and a current of 0·3 ampere was then recorded in the ballistic galvanometer of the external circuit, branched off from the loop. This current was only instantaneous, because the outer circuit now contained resistance in the ordinary state. It is well known, further, that the resistance of some metals increases in magnetic fields. Trying this in helium, Onnes observed that the "threshold value" of the current intensity is altered by the field somewhat as it is by temperature. When the field exceeds a certain strength, the super-conductivity ceases as if the wire had been heated.

In other measurements, the potential differences at the ends of the wires were determined by the potentiometer method. The great trouble in such measurements is, of course, to prevent the inflow of heat through the electric connections. We give one series of results obtained with a mercury wire, 0·0015 sq. mm. in section, 20 cm. long (of a resistance of 130 ohms at ordinary temperature), when cooled to 3·6 deg. K. With currents of 375 amperes, 490 amperes, 500 amperes, and 625 amperes per square millimetre flowing through this wire potential differences of 0, 0·27, 2·12, 12·9 micro-volts were observed; the threshold value was thus exceeded when the current rose above 400 amperes per square millimetre.

It has been thought that the super-conductivity and even the high conductivity of metals at low temperatures might supply us with electro-magnets of enormous strength. In iron-core electro-magnets the saturation of the iron limits the attainable field intensity. Long before that, however, the heat generated in the coils would put a stop to our increasing the intensity of the existing currents. Before hydrogen had been liquefied Perrin suggested cooling the coils by liquid air. Fabry calculated, however, that for a field of 100,000 gauss we would need 100 kw. per second, and seven times that energy for producing the liquid air required to carry off the heat. We should not fare better with liquid helium, and as the magnetic field itself would set up resistance in the coils, the problem looks hopeless. But super-conductors have some odd properties. It proved sufficient to press lumps of lead together as terminals to obtain a super-conducting lead key free of all contact resistance. On the other hand, we have mentioned already that the lead wire (a super-conductor in helium) was simply wound on a brass tube (not a super-conductor). When mercury was drawn into a capillary of steel (instead of glass), the mercury resistance vanished at 4·19 deg. K., as if the steel were an insulator. When brass was coated with a thin layer of tin into which a spiral was then cut, this tin wire did not lose its resistance altogether; in tin coated on manganin the resistance vanished. These experiments were not quite concordant, however, and the explanations suggested are not very convincing.

We come back to the "micro-residual resistance." If that resistance were due to traces of impurities, we should hardly expect a sudden decided drop at a particular temperature, and Onnes observed, in fact, that when he purposely contaminated his super-conducting purest mercury (with gold or cadmium) it remained a super-conductor. We have seen, moreover, that tin amalgam can be a super-conductor, and is, in fact, easily turned into that condition. On the other hand, gold would not become super-conducting; the resistance decreased more and more as the purity was raised, but there was no vanishing point, though we certainly can purify gold well. If the super-conductivity of mercury were to be ascribed to its extraordinary purity, it should only contain 1/1,000,000 of the impurities of the finest gold —which is difficult to believe. Analagous to impurities any want of homogeneity in the wires would favour thermo-electric phenomena, the range of which C. Benedicks has recently extended.*

In the fine wires of Onnes "bad spots" may arise from variations in cross section and from breaks in the continuity of the wire, originally present or formed during the solidification, or crystallisation of the metal. On the whole the regularity of the phenomena seemed to indicate that thermo-electric or electro-thermal disturbances were not at work. But the law of Wiedemann-Franz broke down. According to this law the ratio of the thermal conductivity λ to the electric conductivity κ is the same, $\lambda/\kappa = a\,T$, for all metals at a certain temperature; according to Onnes the coefficient a, is for temperatures below the vanishing point 10^7 smaller than the a for temperatures above that point. Though this law has now proved a stumbling-block for several theories, it is admitted that none of the theories of thermal and electric conductivity, proposed since Drude first attempted a general electronic theory, can be regarded as altogether satisfactory. According to Crommelin the dipole theory which Sir J. J. Thomson outlined in his May lecture† before the Institute of Metals, 1915—which in its origin, it should be noted, dates back to the end of the past century—is the most satisfactory and the only one which accounts for the critical temperature, the vanishing point of the resistance. Kamerlingh Onnes himself pointed out even in 1911, that we must regard the electrons not as frozen up at extremely low temperatures, but rather as being then quite unimpeded in their movements. Following a line of argument of Lenard's, he suggested that, at the vanishing point, the atoms would be so close together that their electrons could pass from one atom to the other without any work having to be done. If we arranged a number of billiard balls in a row, all in immediate contact, and hit the first ball, the last would fly off with the full energy of the blow. The difficulty in such models is that we cannot connect any concise idea with the suggestion of atoms and electrons in actual contact. We know, however, that electric conductivity and thermal conductivity cannot be separated in theory. For this reason the recent papers of Kamerlingh Onnes and his collaborators, Burgess, Cath, Crommelin, Holst, Keesom, Oosterhuis and others, deal with specific and atomic heats, critical points and thermodynamics rather than with electric resistance.

Though ultimately any problem of pure science is a problem of applied science, the technical man may, for the present, rest satisfied with the demonstration of a state of super-conductivity, while doing his best to utilise the peculiar high conductivity and other possible advantages of working at low temperatures without going to extremes. A good deal it would seem, might be done in that field.

* See ENGINEERING, June 18 last, page 831.
† See ENGINEERING, May 21, 1915, page 577.

THE INSTITUTION OF MECHANICAL ENGINEERS.

AN ordinary general meeting of the Institution of Mechanical Engineers was held on Friday last, the 17th inst., at 6 p.m., at Storey's-gate, St. James's Park, Westminster, the president, Captain H. Riall Sankey, C.B., occupying the Chair.

The formal business having been despatched, the President referred to the dinner which had been given during the previous week to the engineering professors of London, with a view to enlisting their sympathies in securing graduates for the Institution. This dinner had proved a great success. He further stated that three centres had sent in requests for local branches, and tentative by-laws or rules had been prepared. A committee was sitting to consider the question of associate members being placed on the Council, but no definite conclusion had yet been reached. Negotiations were also on foot with the Board of Education with regard to the education and training of mechanical engineers throughout the country. The Council regarded this movement as one of great importance, and Members of Council had been appointed to act with a committee of the Board of Education.

THERMODYNAMIC CYCLES AND DESIGN OF INTERNAL-COMBUSTION ENGINES.

A paper, by Dr. W. J. Walker, entitled "Thermodynamic Cycles in Relation to the Design and Future Development of Internal-Combustion Engines," was then read; it is reprinted on page 847 of our present issue.

The President opened the discussion, and remarked that in years gone by such papers had dealt with the theoretical aspect; principally the constant volume cycle, and a little with the constant pressure combination. He thought the author's paper a great advance. Diagram Fig. 11, with others, would enable designers to improve on the design of internal-combustion engines. He objected to the division of the temperatures into eighths in Fig. 11, and preferred tenths. To be useful, the diagram should, of course, be drawn on a large scale. Referring to the formula for efficiency, he had endeavoured to compare this with that given by Mr. Wimperis, but he had been unsuccessful, owing to the notation being totally different. Uniformity on this point would be advantageous.

Mr. E. W. Petter said the subject deserved more attention than it had received. All engaged in the design and manufacture of the internal-combustion engine would welcome the paper. Makers were ready to explore every new avenue suggested by theory. The Diesel engine was developed from theoretical principles. Dr. Walker disapproved of the term "Semi-Diesel," but he thought it was defensible. That type of engine was introduced about 1910. Then the accepted tpye was the low-compression Akroyd engine and the Semi-Diesel was a new form of engine, for which a title was wanted. He would accept some of the blame—or the credit—for the term adopted. The Diesel engine cycle represented the constant pressure cycle, and since the Semi-Diesel engine (called the dual combustion cycle in the paper) was a combination of the constant pressure cycle and the constant volume cycle, the name "Semi-Diesel" was obviously a suitable title for engines working half on one cycle and half on the other, as illustrated in Fig. 3 of the paper. The engine was, moreover, half the price and gave only half the worry of a Diesel engine. Dr. Walker had summarily dismissed the entropy function, but the discussion of the subject was not complete without it. Many features were exhibited in an instructive form in the theta-phi diagram, such as the effect of variable specific heat, the heat losses and gains in compression and expansion and the internal energy of the gas, which by means of it could readily be measured at any point in the cycle. He considered the time would come when the investigation of entropy would enter more than it did at present into the investigation of the thermodynamics of internal-combustion engines. Referring to Fig. 4 of the paper of the dual cycle, Dr. Walker made certain comparisons in favour of this cycle. It was, however, ideal and could not be realised in practice. The toe from c to d would have

to be omitted and the constant pressure line from a to f would be lowered by reason of the partial combustion of b to a. All solid injection engines partook of the property of dual combustion. The first part of the charge served to raise the compression pressure, while, in some cases, the injection of the remainder was deliberately prolonged in order to obtain the constant pressure effect.

The dual-combustion cycle with extended expansion, even if it were practicable, would seriously diminish the mean effective pressure; but, from a theoretical point of view, the cycle was interesting, because the efficiency, instead of increasing with the compression ratio (r) passed through a maximum value with increase of r. He fancied that Dr. Walker had forgotten that in the combustion from b to a, oxygen necessary for the combustion from a—f was being used and the constant pressure line a—f was not attainable. Fig. 11 would be very serviceable in the investigation of a thermodynamic cycle. He thought an example of the use of a diagram in the case of a Diesel engine cycle might be added. He regretted that in the paper a *cachet* had been put upon the use of water injection. Whatever system was ultimately adopted for utilising waste heat, water injection for any purpose was ruled out. If the water contained lime, this was deposited on the cylinder walls and on the piston with obvious results. If the fuel obtainable contained a high percentage of sulphur sulphuric acid was formed and the engine being rapidly destroyed.

Mr. W. J. Stern, of the Air Ministry Laboratory, remarked that on the previous evening Mr. H. R. Ricardo had read a paper at the Aeronautical Society (referred to elsewhere in this issue) which dealt with the very point under discussion. Mr. Ricardo had shown that the cycle adopted in the present internal-combustion engines was most efficiently carried out, the engine yielding as much power as could be given with that cycle, using the accepted working substance. There was, therefore, little chance of improvement in that direction. Both he (the speaker) and Mr. Wimperis had at once realised the importance of the author's paper, in so far as it opened out the trial of a cycle differing from the ordinary one. Some of Dr. Walker's claims were open to doubt. In the particular diagram taken by Dr. Walker ($a = 1{\cdot}7$, $\rho = 2$, $v = 13$) the efficiency of the Diesel cycle section was about 59 per cent., with a compression ratio of 13 : 1. If to this were added part of a constant volume cycle, with a compression ratio of 9 to 1, the latter part would give an efficiency of 62·1, and the mean of the two together would be 59·7. He drew the conclusion that in the case of the Diesel cycle it paid to add heat at a greater efficiency than 59 per cent., below which further addition of heat lowered the total. The dual combustion cycle would thus have a slightly higher efficiency for a smaller compression ratio, the expansion ratio being the same as before. The speaker agreed with Mr. Petter that, in criticising any cycle, the entropy diagram was necessary, to show what the engine was doing. The entropy diagram disclosed the fact, not otherwise readily perceived, that in a Diesel engine as much as 10 per cent. of the entire heat was added at constant volume and the remainder at constant pressure; that, therefore, the Diesel cycle was not a constant volume cycle, but a sort of dual combustion cycle.

Taking relative units, the Diesel cycle, with T as the temperature at end of compression, would take 0·408 T units of heat and the constant volume cycle 0·119 T units, taking Dr. Walker's figures for $a = 1{\cdot}7$, $\rho = 2$ and $v = 13$. The dual combustion cycle would take the sum, *i.e.*, 0·527 T. The foregoing figures assumed constant specific heat. If the temperature of an ordinary Diesel cycle was 2,000 deg. C. (assuming constant specific heat) the dual combustion cycle would theoretically have a top temperature of over 3,000 deg. C. Of course, these temperatures can only be taken as relative. The higher temperature, in the case of the dual combustion cycle, would certainly lead to difficulties, mainly in the cooling of the piston and valves—the great difficulty in aero engine design. With large sizes of engine it would be hopeless to raise the temperature in this manner unless water were injected—or something like that was done; this would introduce other troubles. Dr. Walker gave an example of the constant volume cycle with a sloping combustion line, and, according to his analysis, the cycle would have a greater efficiency than that of the constant volume cycle. The speaker's experience showed the contrary; the more rapid the heat addition (even up to detonation) the greater the indicated efficiency, the reason being associated with the cooling, neglected in Dr. Walker's analysis.

Mr. A. E. L. Chorlton said classification of internal-combustion engines presented great difficulties, and he had hoped that Dr. Walker would have been more specific in dividing the various cycles, &c. Practically, the author had dealt with nomenclature under only three heads. He had emphasised the advantages of extended combustion, in which, however, there was really not very much. Personally, he saw greater advantage in the longer expansion stroke. This matter had been dealt with by Mr. Ricardo in his paper before the Royal Aeronautical Society, read the previous evening. Dr. Walker's best example was the Humphrey pump, which had a 3 : 1 expansion stroke. In the aero engine it was desirable to vary the stroke so as to provide a long suction stroke when leaving the ground—the largest amount of mixture being drawn in—followed by a short expansion stroke, while, in the air, the reverse was aimed at, namely, a short suction stroke and long expansion stroke. The question of the dual combustion engine was very important. The hot-bulb engine could not be described as a dual cycle engine. The diagram showed heat added at the end of the compression stroke, but in the case of any uncooled surface heat was being added all the time. It seemed, therefore, that the Blackstone engine, mentioned in the paper, was the only applicable type, the heat being put in right at the end of the compression.

The Sabathé, De La Vergne and the Trinkler-Körtung, had also been mentioned, and the speaker would ask why these engines, all of foreign origin, had been named, suggesting that nothing was being done in this country. Were they strictly of the dual-combustion type? The Trinkler-Körting had a sort of self-created air injection at the end of the stroke, and was, he believed, a Diesel engine. With regard to the sloping admission line, this, after all, was really ignition, and was a favourite way of working an engine when used with an exhaust boiler. To that extent Dr. Walker was correct, and better results were obtained in the case of an exhaust boiler. He was disappointed with the author's observations on regeneration, and thought it should have been treated as a theoretical and mathematical proposition, as the author had treated the dual combustion cycle. In one way or another more than half the heat was leaving the engine, and a theoretical investigation was most likely to reveal some method of utilising it. The admission of steam to the cylinder was questionable practice, and he doubted whether the return suggested would be obtained from the turbine. Referring to the Rateau turbine, used for super-charging, two fluids in an engine would set up certain difficulties. Finally, he would ask if the author could not give an analysis of an engine which was a combination of a hot air engine and an internal-combustion engine.

Mr. F. L. C. Martineau alluded to the chart, Fig. 11, which however, like the Mollier diagram, facilitated error in tracing the points across it, vertically or horizontally; it could better be applied by conversion into an alignment diagram. The Mollier diagram had been so converted, and was more useful, because of direct reading; all figures could be interpolated without risk of going wrong in direction. On the subject of regeneration he thought Dr. Walker's example were unfortunate, as they showed that by injecting water the combustion efficiency was decreased. Whatever the form of regenerator used it should not reduce the original efficiency of the engine on the combustion cycle. What was then gained would be only a percentage of a larger loss. The figures of typical results showed an actual loss of 3 per cent. brake horse-power 33 per cent. to 30 per cent.—while the problematical gain was only 8 per cent. The Still cycle, referred to in the paper, not only gave the properties due to converting heat into steam, but also put the combustion cylinder into such a condition that there was an actual gain, and not a loss, on the combustion cycle; this was due to the constant and uniform temperature of the cylinder itself. That was the important feature of it. Not only was there gain from regeneration, but from the cylinder, for the reason that the amount of heat transmitted from the combustion cylinder to the jacket was a much smaller percentage than in a normal engine. As a matter of fact, it was only about 10 per cent. of the heat.

Mr. W. A. Tookey gathered, from the paper and the diagrams exhibited, that Dr. Walker expected to maintain in an engine a mean effective pressure from anything up to 200 lb. per square inch, at which the speaker's imagination boggled. Such an engine was more than could be hoped for. He should much like to think it possible, as until such mean effective pressures could be obtained, there was little hope of extending the application of internal-combustion engines in such confined places as were inevitable with marine propulsion. Dr. Walker had not considered how much depended upon the fuel available for use in the internal-combustion engine. It was possible to do with gas what could not be done with oil, and *vice versa*. The fuel used would have to be taken account of in the system of classification under consideration by the committee of which Mr. Chorlton and he were members.

He had been disappointed to find that even in the case of such a school as the Manchester School of Technology, there were professors who held a favourable view of water injection into the cylinders of internal-combustion engines. The chart which Dr. Walker had drawn up conformed to a method adopted by the speaker, and dealt with in the paper he had read before the Institution in 1914, for computing the compression ratio. The paper stated, however, that "the indicated mean effective pressure of the engine, which was evidently in bad tune when Mr. Tookey first tested it, was subsequently raised to 96 lb. per square inch, a decided improvement over its original value, but not so good as would appear to be obtainable in a well-designed engine." That was not then known; they had not the advantage of Dr. Walker's paper in 1914. He would have been surprised to find any mean pressure over 100 lb., and even would have taken steps to reduce it. Any mean pressure in the internal-combustion engine which exceeded 95 lb.—certainly 100 lb.—was unsafe at the present time. Dr. Walker might be right, and the engine might have reached the figure given, but he, the speaker, would have endeavoured to get the efficiency with a safer mixture.

Mr. L. St. L. Pendred, referred to the interesting comparison made by Dr. Walker between the uniflow engine and a gas engine, showing a curious resemblance between the two engines, in that the efficiency increased as the compression went up. He could not think there was any real physical basis for that, but it was a remarkable coincidence, and he hoped the matter would be followed up. Frequent reference had been made in the paper, and the discussion to "constant pressure," and "constant volume" cycles, and, apparently, neither, expression was a correct definition. One of the subjects that might come before the Nomenclature Committee was whether terms which did not accurately describe a cycle should be retained.

The President referred to the use of the theta-phi diagram. With a certain condition of mixture a cycle was plainly shown on this diagram and the efficiency of the cycle was the ratio of the area bounded by the two verticals and two curves, to the area bounded by the two verticals, the combustion curve and the base line, or the total amount of heat produced within the cylinder walls. If the compression ratio were changed for a greater one it was necessary to find a point at which the new area for work done was the same as before. The work produced in the cylinder was the same, but the area which represented it was much greater in proportion than that representing the total heat produced in the cylinder, and, therefore, the latter cycle with a higher compression ratio was obviously more efficient than the first one; therefore as compression increased greater effi-

4,500-LB. PRESSURE SIX-STAGE AIR COMPRESSOR.

CONSTRUCTED BY MESSRS. PETER BROTHERHOOD, LTD., ENGINEERS, PETERBOROUGH.

(*For Description, see Page* 830.)

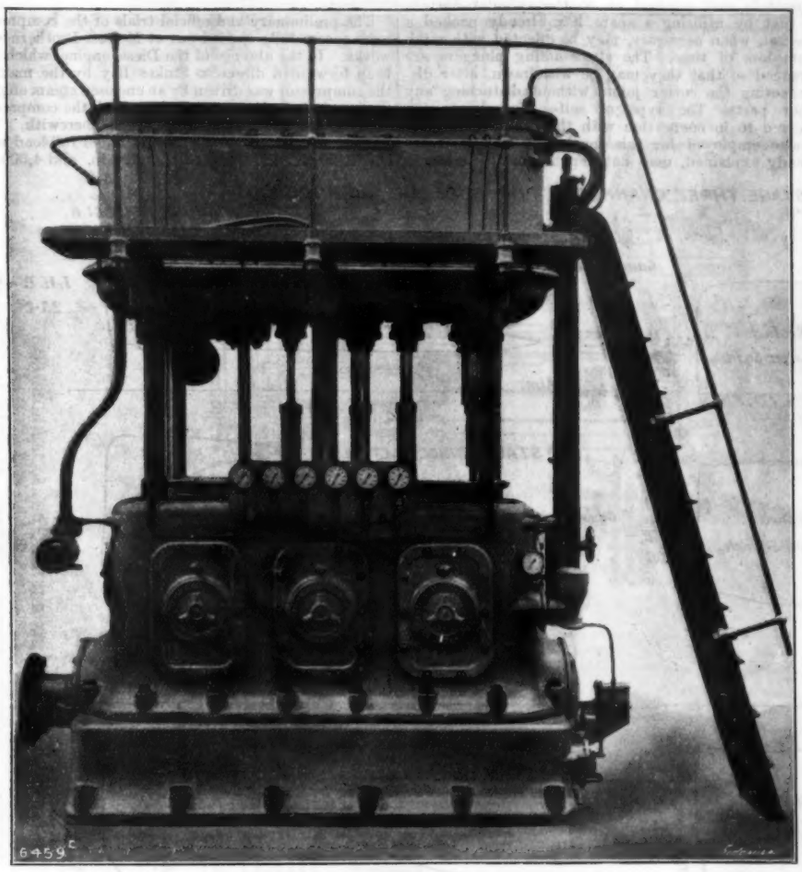


FIG. 13

ciency was attained. That was true, whether there was constant pressure combustion, or whether the specific heat varied with temperature. The cause of the greater efficiency with increased pressure in the case of the uniflow engine was, he thought, that the cylinder walls were warmer and there was less initial condensation.

Dr. W. J. Walker then replied to the discussion. With regard to the division of the diagram into eighths (Fig. 11) instead of tenths, for the last two years his students had drawn up diagrams and had adopted tenths. He had submitted the actual original diagram for publication, and the division was ruled by the paper available at the time. As to the similarity between Mr. Wimperis' formula for the efficiency of the cycle and his own, he would say that the one could be directly translated and represented in terms of the other; both were exactly identical. He had, however, obtained his formula in quite a different way. Mr. Petter took exception to his criticism of the term "semi-Diesel." The Petter engine, and several others of the type, did not give constant-pressure combustion; he had looked in vain for the constant-pressure line in any of the diagrams he had available. In the case of the Blackstone, the constant-pressure line was very distinct, as was also the differentiation between the constant-volume combustion process and the constant-pressure combustion process, a sharp angle signifying change from constant-volume to constant-pressure combustion. With regard to the Sabathé, De La Vergne and Trinkler-Körting cycles, his reason for referring to these was that he took the Blackstone as the typical English engine, the Sabathé as the typical French, the De La Vergne as the typical American, and the Trinkler-Körting as the typical German. The last-named had not had much development, but the diagram in the paper, and that which he had exhibited, distinctly showed the two stages of combustion. He had stated that the engines were operated approximately on the dual combustion principle—as far as could be judged from published diagrams. He had been completely satisfied with the pressure-volume, temperature and energy quantities. He would not say that the entropy function was of no use, but in general design and other work it was not invariably required.

The practicability of the cycle had also been referred to. The dual combustion gave increased efficiency at a lower compression ratio. His favourable opinion of the dual combustion cycle was based entirely on the fact that with it the compression ratios could be reduced, so diminishing mechanical losses, in itself an advantage. He agreed that the temperatures were higher. That point was raised in the paper, and, as shown, in the comparison, the maximum efficiency curve was obtained. With regard to the sloping combustion line, his experience, even with slow-speed gas engine work, was opposed to that of Mr. Stern; a slight slope from the vertical line gave higher efficiency. There was, perhaps, little in it, but the engine ran better mechanically and gave a higher over-all efficiency. He did not suppose it gave a higher indicated efficiency. There was, of course, a limit, which from his tests, he made out to be the ratio of volume V_1 to V_2 equal to 1·2. Anything beyond that, of course, further diminished efficiency. In relation to the classification suggested, he would say that he had merely submitted it tentatively, as possibly, clearing the ground. It was his own classification, used by him when lecturing to students. He was continually asked why the term "semi-Diesel" was used, but could give no satisfactory reason. These terms were opposed to scientific definition. Mr. Chorlton had also alluded to water injection. It was needful to make assumptions when treating of water injection, but it was impracticable to say whether they were justified or not. Mr. Chorlton laid emphasis upon the two-fluid aspect of the matter. Of course, the gas from an engine, even without water injection, consisted of several fluids; CO_2, steam, nitrogen and so on, were already in the gas, and the addition of steam did not make much difference.

Mr. Chorlton here observed that the question was one of the proportion of steam, but he had not really raised that point. What he had asked the author to do, if he could, was to treat mathematically a combination between an ordinary internal-combustion engine and an ordinary hot-air engine.

Continuing, Dr. Walker said that the curves of the uniflow engine were obtained from theoretical conclusions, not from practical data, and therefore the point raised by the President, as to higher efficiency in the case of the uniflow engine, being due to diminished condensation would not hold; the curves were deduced from the cycle of the engine, in which cycle superheated steam was used, this corresponding closely to a gas.

The President then stated that the paper would be further discussed on the 23rd inst. (yesterday) at the Engineers' Club, Manchester; and that an informal meeting would be held at the Institution on Friday, January 14, 1921, to discuss "Road Transport Machines and Roads." The subject would be introduced by Mr. S. G. Williams. He also stated that the next general meeting would take place on Friday, January 21, 1921, when a paper on "The Mechanical Loading of Ships" would be read by Mr. H. J. Smith.

WIRE ROPES FOR SOUTH AFRICA.—It is understood, says *The South African Mining and Engineering Journal*, that the Rand is shortly to have its own wire rope manufacturing works, and that a well-known agent and importer of this essential commodity has resigned his connection with the British manufacturers, and has acquired the shops of a large mine recently closed down in the Germiston district, with the object of turning them into a wire rope works. Wire ropes to the value of 282,897*l.* were imported last year. The finest steel wire will, of course, be imported, and highly skilled labour will also have to be brought from oversea. It is thought in some quarters, that the mines will encourage the project in order to counteract the efforts made by British manufacturers to eliminate competition in this line and to form something said to approach closely to a "ring."

DIFFUSION IN LIQUID LEAD.—From the rate of diffusion of particles through a liquid medium conclusions can be drawn as to the size of the particles. In ordinary diffusion, however, there is a possibility of a reaction between the particles (or solute) and the medium (or solvent) through which they move. Hence Maxwell suggested that diffusion experiments should be conducted under conditions such that particles and medium were of the same material. For that purpose an attempt should be made to mark certain particles, without affecting their properties, so as to be able to trace their movements. In the case of fused lead G. von Hevesy and J. Groh have done this at Copenhagen, with the aid of the radioactive isotopes of lead (*Zeitschrift für Elektrochemie*, September 1). That the masses of the isotypes are not the same should not make any difference. They took a rod of lead, 3 cm. long and fused it in an evacuated glass tube; on the top of the liquid column they poured 1 cm. of radioactive lead (from thorium B or radium D). The solidified rod, now 4 cm. long, was placed in an electric furnace and heated for two days up to 343 deg. C., *i.e.*, 20 deg. above the melting-point of lead. The cold solid rod was then cut into four equal cylinders; the pieces were rolled out and tested for radioactivity. The distribution of the radioactive lead in the fused ordinary lead was thus determined. The diffusion rate observed was 2·29 cub. cm. per day, at 343 deg. C. The diffusion constant of the lead-ion in aqueous solution is about 0·68 cub. cm. per day at 18 deg. C. The comparison between the two figures is difficult, because diffusion is assumed to be proportional to the absolute temperature and inversely proportional to the viscosity. The viscosity relations are not known; the lead ion, moreover, probably travels with a water envelope, and one cannot say whether the particles of fused lead are atoms or molecules. But it would appear that the fused lead atom diffuses in lead about three times as fast as the lead ion moves in water, and the research is interesting.

HIGH-PRESSURE AIR AND GAS COMPRESSORS.

(Concluded from page 802.)

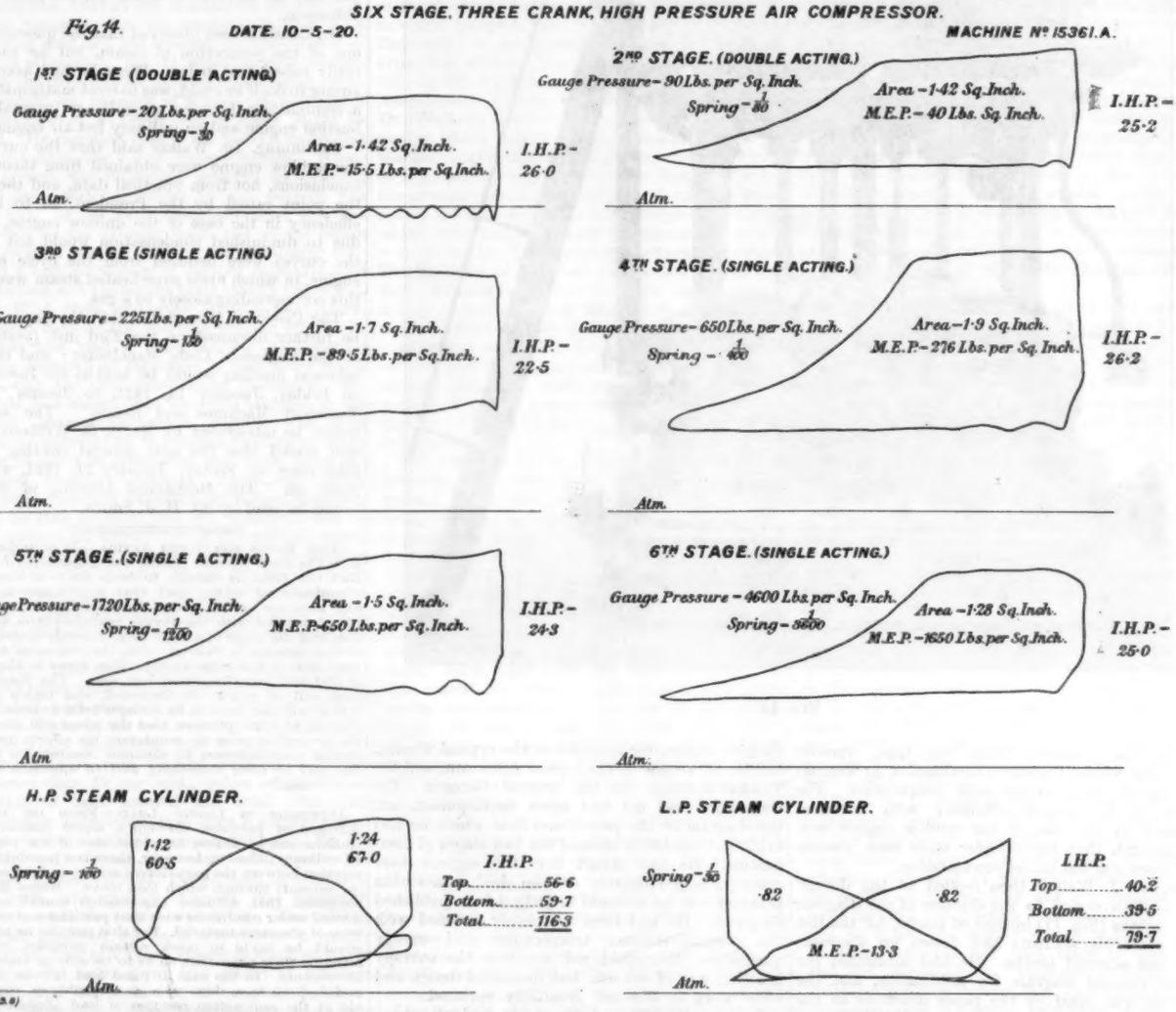
IN our article of last week we referred briefly to a 4,500-lb. compressor built by Messrs. Brotherhood. A general view of this very high-pressure machine is given in Fig. 13 on page 829, while sectional views showing its detailed arrangements are given in Figs. 15 to 17, on page 831. It need hardly be said that the necessities for sound mechanical construction and careful design, particularly of valves and packings, which exist in reference to the 2,250-lb. compressor described last week, apply with even greater force to the 4,500-lb. machine with which we are now concerned. The compressor was built to the order of the Admiralty for the Naval Experimental Station at Stokes Bay. It was designed to deliver 60 cub. ft. of air per hour at a pressure of 4,500 lb. per square inch., when running at 250 r.p.m. When tested the compressor gave an actual output of 62·8 cub. ft. per hour, thus showing a satisfactory margin over the quantity specified. In addition to this machine, Messrs. Brotherhood also supplied three two-crank five-stage machines for the same station, for compressing air to 3,000 lb. to 3,500 lb. per square inch. These machines are generally of similar construction to the one we illustrate. All the compressors are driven by direct-coupled Diesel engines and the four sets, together with their air reservoirs and accessories, which are arranged in a specially constructed building, form a probably unique high-pressure air-compressing plant.

The arrangement and details of the 4,500-lb. compressor are well shown in Figs. 15 and 16. In its general lines it follows the 2,250-lb. machine illustrated in our previous article. As will be seen from Fig. 15 the cylinders are arranged in line two stages to each crank and crosshead. The first and second stages are double-acting, the remainder being single-acting. For the first five stages the cylinders are made of cast bronze, while for the sixth stage the cylinder and valve chest are machined from a solid steel forging. The plungers of the last four stages are made from heat-treated chromium steel. As in the 2,250 lb. machine, all plunger packings are of the metallic type, while the packing boxes are made separately and screwed on to the cylinder barrels, so that by utilising a spare box already packed a renewal, when necessary, may be effected with minimum loss of time. The single-acting plungers are arranged so that they may be withdrawn, after disconnecting the cotter joint, without disturbing any other parts. The type of self-sealing joint ring referred to in connection with the other compressor is also employed for this machine. This joint, as already explained, does not depend for its tightness on the stress put on the securing bolts of the covers, so that no heavy screwing-down work is necessary even for the highest pressures.

The arrangements of the intercoolers of the machine will be followed from Figs. 15 and 16. They are all submerged in a tank which surrounds the cylinders and through which water is continually circulated. This water flow bathes the outsides of the six cylinders and valve chests as will be clear from the figures. Water is also injected into the compressed air circuit to facilitate cooling and to lubricate the plungers. Oil is not necessary for this latter purpose and is not used in cases where traces of lubricant in the discharge would be objectionable. From the cooler of the sixth stage the compressed air passes through a steel separator bottle fixed in a vertical position and shown to the right-hand side of Fig. 15. In this bottle the injected water is deposited and drained away, the air being finally discharged to the storage reservoirs. In other particulars the compressor follows the one described earlier, the valves for the first three stages being of Messrs. Brotherhood's "Mesta" light plate type and for the remaining stages of the spring-loaded poppet type. An enlarged view of the valves of the first three stages is given in Fig. 17. The under part of the compressor follows the firm's high-speed engine construction. Forced lubrication is arranged for and the oil strainer is duplicated, each strainer being attached to a sliding frame so that either strainer can be removed for examination while the set is running.

The preliminary and official trials of the compressor were successfully carried out at Messrs. Brotherhood's works. In the absence of the Diesel engine, which had been forwarded direct to Stokes Bay by the makers, the compressor was driven by an enclosed steam engine. Copies of the indicator cards from both the compressor and the engine are given in Fig. 14 herewith. The pressures registered by the gauges under full load were 20 lb., 90 lb., 225 lb., 650 lb., 1,720 lb. and 4,600 lb. per square inch in the respective stages. These figures correspond very closely to those obtained theoretically by assuming an equal ratio of compression in each stage. The total indicated horse-power of the air compressor taken from the indicated cards was 150 and that of the engine 196. These figures show an overall efficiency of 76 per cent., which may be regarded as a very creditable performance. In conclusion, and in connection with Fig. 14, it should be pointed out that the engine used for testing purposes was designed for condensing conditions, but that during the trials it was exhausting to atmosphere. This accounts for the uneven distribution of power in the high-pressure and low-pressure steam cylinders.

Fig. 14. SIX STAGE, THREE CRANK, HIGH PRESSURE AIR COMPRESSOR. DATE. 10-5-20. MACHINE No 15361.A.



(6453.8)

JOINT RAILWAY MANAGEMENT.—Mr. Arthur Watson, C.B.E., General Manager of the Lancashire and Yorkshire Railway has been appointed to the London and North Western Railway to follow Sir Thomas Williams when the latter retires shortly. Mr. Watson will retain his position on his present line, and the two will be managed jointly, by the agreement of both boards.

4,500-LB. PER SQUARE INCH SIX-STAGE AIR COMPRESSOR.

CONSTRUCTED BY MESSRS. PETER BROTHERHOOD, LIMITED, ENGINEERS, PETERBOROUGH.

(For Description, see opposite Page.)

Fig. 15.

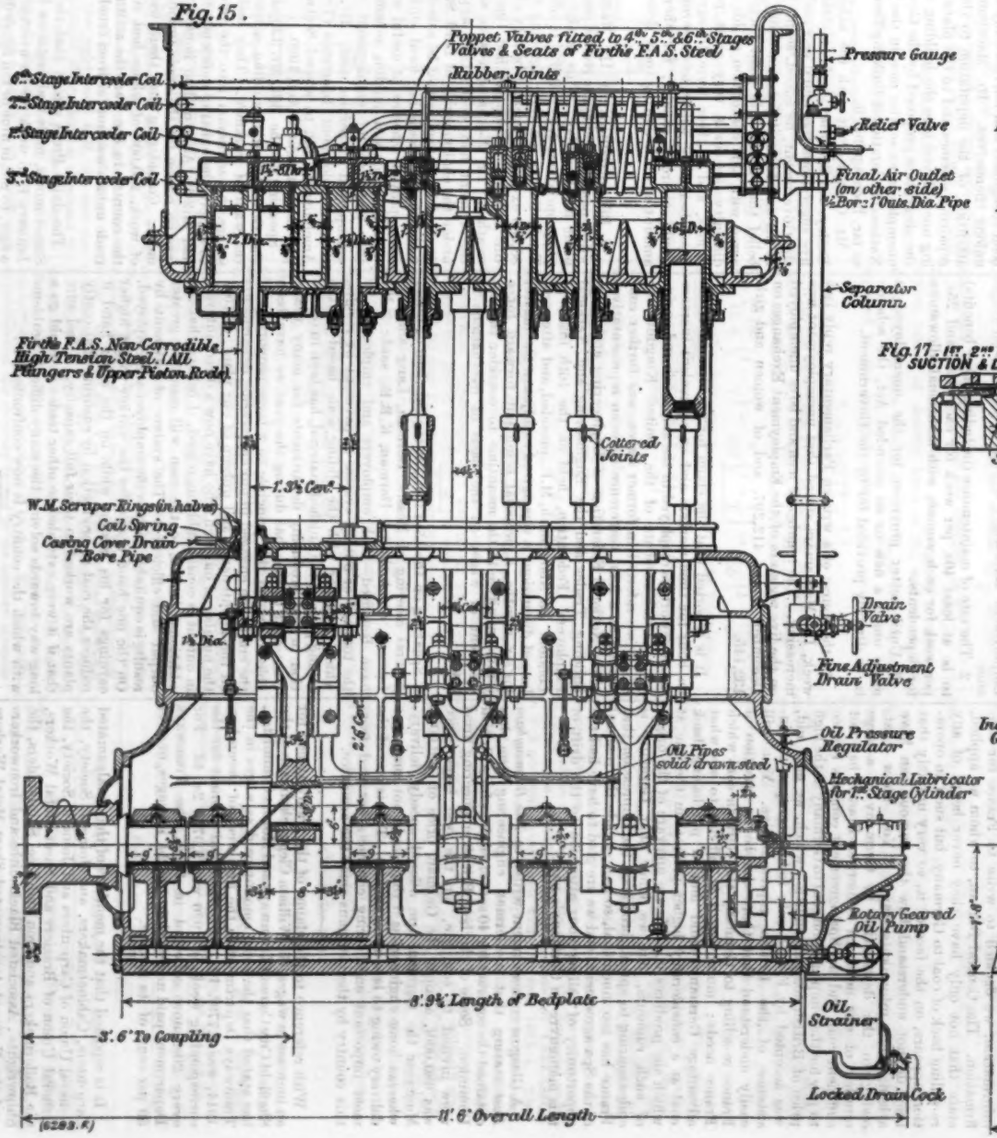

Poppet Valves fitted to 4th, 5th & 6th Stages
Valves & Seats of Firths F.A.S. Steel
Rubber Joints
Pressure Gauge
Relief Valve
Final Air Outlet (on other side) ½ Bore 7 Outs. Dia. Pipe
6th Stage Intercooler Coil
2nd Stage Intercooler Coil
1st Stage Intercooler Coil
3rd Stage Intercooler Coil
Separator Column
Firths F.A.S. Non-Corrodible High Tension Steel. (All Plungers & Upper Piston Rods)
Cottered Joints
W.M. Scraper Rings (in halves)
Coil Spring
Casing Cover Drain 1" Bore Pipe
Drain Valve
Fine Adjustment Drain Valve
Oil Pressure Regulator
Oil Pipes solid drawn steel
Mechanical Lubricator for 1st Stage Cylinder
Rotary Geared Oil Pump
Oil Strainer
Locked Drain Cock
8'. 9¾" Length of Bedplate
3'. 6" To Coupling
11'. 6" Overall Length

Fig. 16.

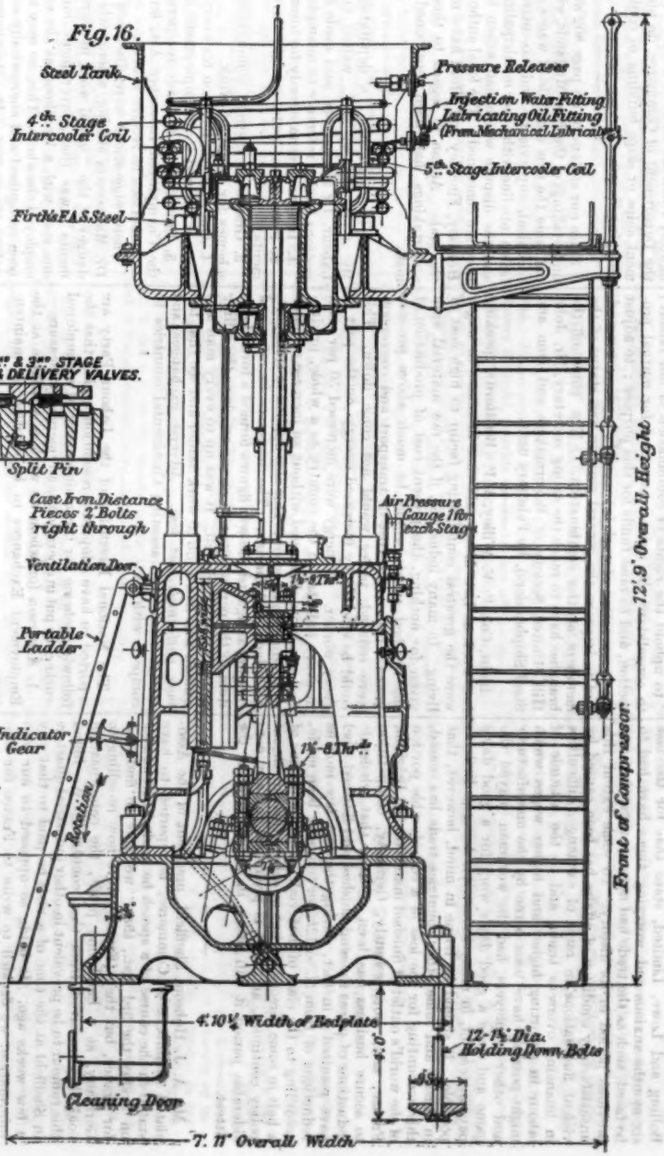


Fig. 17. 1ST, 2ND & 3RD STAGE SUCTION & DELIVERY VALVES.

INDUSTRIAL NOTES.

IN their trade review for the current year, Messrs. Bolling and Lowe, Limited, state that for the last six months anxious and worrying times have had to be faced, such as the trade had not experienced at any previous period in its history. To some extent this unsatisfactory condition of affairs has been caused by violent fluctuations in rates of exchange, difficulties in financing overseas trade, and to the attitude of labour in extorting higher and higher wages which might possibly have been borne by the manufacturer and other employers, had the workman played the game and done a good day's work for a good day's pay, instead of, in many industries, doing as little as possible. It should be borne in mind, however, that in Russia and some other countries trade has ceased, this accounting for the loss of a considerable portion of the world's outlet of finished material. In Belgium, France, and, more recently, Germany, competition to secure business has been so keen that wholesale reductions of prices for semi-finished and finished steel have resulted; in fact, during the last few months reductions of from 5*l.* to 12*l.* per ton have been made, according to the class of material. There are signs of a halt in some directions, but in others this cut-throat policy continues, and if it is prolonged for any considerable period it will result in the survival of the fittest.

Mr. A. J. Hobson, Sheffield, president of the Associated Chambers of Commerce, is reported to have stated in the course of a speech he made in Newcastle on Friday the 3rd inst., that "we were to find coal for France, but they (France) were now re-selling to Germany, at a handsome profit, the compensation coal they received from that country." We found this rumour to be prevalent in other industrial quarters in Sheffield at the time of a visit he paid to that city a few weeks ago. It being so opposed to our own information, we decided to write to France for confirmation. The Central Bureau, to whom we applied, state that not only have they never heard of any re-selling back of coal to Germany, but such an operation appears, on the face of it, so very unlikely that they do not understand how the rumour can have arisen. Our informants say: "You know that, owing to the destruction by Germany of a large number of our northern collieries, France has not sufficient coal, and the Spa agreement compels France to pay for the compensation coal to Germany at the high price of British coal, a condition which, we may add, was accepted by France only following upon the insistence of the British representative. You will easily understand that there can be no question of France re-selling to Germany the German coal which France needs; moreover, it is difficult to see what advantage Germany could find in purchasing back coal at a considerably higher price than the one at which she produces it. We are unaware of the origin of such rumours, but we know that Germany is endeavouring to spread broadcast the impression that France has too much coal, so as to evade the renewal of the Spa agreement, and we are glad to have had the opportunity of calling your attention to the drift of this manœuvre on Germany's part."

A Glasgow correspondent writes to *The Birmingham Post* stating that a German engineering firm has obtained the contract for 40 sets of engines for a British Dominion. Some of the best British engineering firms were invited to compete, but the best home price was 680,000*l.*, against the German price of 400,000*l.* Moreover the German firm offered speedy delivery, whereas home engineers said they could not guarantee delivery owing to labour conditions. This is one of the most important engineering contracts wrested from this country by the Germans since the armistice.

With reference to the claims of the tramwaymen for an increase in wages, Sir William Clegg, chairman of the Sheffield City Council Tramways and Motors Committee, has stated that the total amount paid as wages in the Tramways Department in the first week of December, 1914, was 2,779*l.* 10*s.* 9*d.*; the total amount for the corresponding week in 1920 was 9,976*l.* 2*s.* 4*d.* For every 20*s.* now collected in fares, the Tramways Department paid no less than 10*s.* 2*d.* in wages, or over 50 per cent. of its income.

It is reported that the members of the Amalgamated Carpenters, Cabinetmakers, and Joiners' Society, the General Union of Carpenters and Joiners' Society, the General Union of Braziers and Sheet Metal Workers, the Boilermakers and Iron and Steel Shipbuilders, the Shipwrights', Associated Blacksmiths and Ironworkers and the National Amalgamated Sheet Metal Workers and Braziers' Societies are to vote upon a proposed working agreement for these unions to be known as "The General Combination of Ship-constructional and Engineering Workers."

The objects of the linking-up of these societies are "to uphold the rights of combination of our labour; to consolidate the unions concerned for mutual protection, and to raise funds for this purpose; to adjust the demarcation of work between the trades concerned, and to improve the general position and status of the members of the combination." The votes of the branches have to reach the acting secretary, Mr. John Hill (United Society of Boilermakers and Iron and Steel Shipbuilders), by February next.

Lieut.-Col. F. V. Willey, M.P. (Bradford), speaking last week at Low Moor, said that increases in wages were the greatest contributing factor to high cost of living. In many industries, if the raw material were given for nothing, the present cost of production of the finished article would be much above pre-war prices. Unless the cost of transport and conversion were reduced, prices would not come down. This could be effected by increased energy on the part of every worker. If energy were increased 50 per cent. in every industry in the country as a whole, production would be cheapened without an increase of hours or a reduction of wages. This also applied to transport, both land and marine. The increases in rates and freights as against pre-war figures formed a formidable item in the percentage cost of any article as the selling price of the article fell. It was up to every man and woman who had a job to work harder and see that the task performed cost less. Adverse exchanges and harder work were assisting Continental countries to compete with us.

The National Executive of the Labour Party are reported to have adopted a resolution urging that the following scheme for the maintenance of unemployed workers be put in operation as an emergency measure:—

1. A person for whom no work is available at the Employment Exchanges to be entitled to maintenance.

2. The rate of maintenance (including other benefits) to be at least 40*s.* per week for each man and 25*s.* per week for each woman, with additional allowances for dependents.

3. Until better provision for the unemployed is made under a new or an amended Act, the scheme to be directly provided for by the Government.

In the course of a written Parliamentary reply last week, Dr. Macnamara stated that unemployment was increasing. The number of men and boys unemployed on the live registers of the Employment Exchanges on December 3 was 412,297, and of women and girls 132,145.

It is reported that the claim for an increase of 6*d.* an hour for time workers and an equivalent increase for pieceworkers employed in the shipyards and engineering establishments of the United Kingdom, to which we referred in former issues, was further considered at a joint conference between representatives of the National Federation of Engineering and Shipbuilding Trades and the Engineering and National Employers' Federation, held on the 16th inst., in London. Sir Alan Smith, M.P., presided, and after prolonged discussion, it was agreed to adjourn the matter for six months, a proposal being put forward for a joint committee in the meantime to consider the adjustment of wages on the basis of fluctuations in trade.

Speaking on the 15th inst., at the thirtieth ordinary general meeting of Messrs. Dorman, Lang and Co., Limited, Sir Arthur J. Dorman, K.B.E., said: "We have benefited—both employers and employed—by the tonnage or output system of payment by results, which, together with the sliding scale based on the selling price of the finished material, has been in operation in the producing departments for many years. I am glad to say that during the year we have been able to extend this principle to a large proportion of the craftsmen engaged in our engineering departments on the maintenance and upkeep of our plant, so that the number of our men who have now a direct interest in output is considerably increased. I believe that the additional benefit to the men will result in greater output and efficiency. The system of payment by results is equitable both to the employer and employed. On the one hand it enables the worker to get higher earnings for his labour, while on the other hand it reduces the cost of production by ensuring that costly plants are worked to their full capacity. I feel sure that if it were extended to other trades it would go a long way towards solving the many difficult problems with which the country is now confronted. . . ."

We read in *The Iron Age*, New York, that American shipyards were building or under contract to build for private shipowners, on November 1, 334 steel vessels of 1,206,486 gross tons, compared with 330 vessels of 1,236,327 gross tons on October 1. These figures, which are those of the Bureau of Navigation of the Department of Commerce, do not include Government ships or ships building or contracted for by the Shipping Board.

Since our statement on page 802 *ante*, the electricity undertakings of the East Midlands, which were standing out from the new schedule of wages and conditions for technical, supervisory and executive engineers, have fallen into line with other municipalities and companies, and the dispute which had arisen is settled so far as they are concerned. The local authorities of Hackney, Hornsey, Finchley and Ilford have not yet recognised the scale. Action in regard to these four electricity undertakings has been postponed until the 30th inst.

On the 16th inst., a deputation, introduced by Mr. J. R. Clynes, M.P., waited on the Minister of Labour, Dr Macnamara, and made the following suggestions having reference to unemployment:—

1. Insurance is no remedy for unemployment.

2. Provision of useful work in Government establishments.

3. Grants to distress committees to finance local schemes for providing work.

4. Out-of-work donation for every unemployed person not covered by unemployment insurance.

5. Provision to be made for persons coming under the Unemployed Insurance Act, but not qualified by contributions to receive benefit.

These suggestions were discussed at the interview, Dr. Macnamara stating, among other points, that the danger of the "useful work in Government establishments" was that Government might thus provide one man with a livelihood at the expense of another employed elsewhere. This, we may add, has frequently been recognised and energetically combated by trade unions themselves. Dr. Macnamara also called the attention of the deputation to the road making and repairing schemes and to the plans prepared for drafting unemployed into the building trade. In regard to the absorption proposed by the Government, of 50,000 unemployed ex-service men in the building trades, the National Federation of Building Trade Operatives, have, so far, been against it.

Mr. Clynes dealt with the subject in a speech at Batley, last Saturday, and complained that none of the five suggestions was found acceptable. The remedy of the Government, he added, seems to be to do nothing at all and to wait for something to turn up, in the belief that things will right themselves. We do not agree with this contention of his; to our mind, the difficulty lies for a very great part with the trade unions, and if these were to agree to pull together whole-heartedly with the Government, the situation would improve rapidly, for there is an enormous amount of work waiting to be done.

A Bill introduced by Dr. Macnamara for dealing with unemployment was read a second time in Parliament last Tuesday. This is the Consolidated Fund (Appropriation) No. 2 Bill. It offers to the Building Trade Unions, on their agreeing to absorb and train 50,000 ex-Service men, a bounty of 5*l.* per man. The Bill makes provision for lost time by reason of bad weather. Dr. Macnamara also announced that the Government had decided to appoint a Committee under the chairmanship of Lord St. Davids, at whose disposal Parliament would be asked to place the sum of 3,000,000*l.* for assisting local authorities in carrying out approved schemes of useful work other than the work on roads and building schemes. In this connection preference of employment would be given to unemployed ex-Service men. He, further, brought in the Unemployment Insurance (Temporary Provisions Amendment) Bill, to amend Section 44 of the Unemployment Insurance Act, 1920.

Speaking on the Bill, Mr. Lloyd George stated that the Government's building scheme was held up for the want of workmen. They had done their best to secure the admission into the building trade of men to supply the existing deficiency in labour, but so far had failed. As a million houses were required there was no reason for the trade unions to fear unemployment. Considering that there were 500,000 men out of work, 250,000 of whom had risked their lives for the country in the war, the attitude taken up by the trade unions was not far from cruel.

The daily Press report that the workers in United States mines, mills and factories have agreed, as from January 1, to work for an average of 25 per cent. less wages, to put in nine or ten hours daily, and to abandon the old scale of time and a-half for overtime, and in many cases to take up again the method of piecework.

"TIDAL POWER DEVELOPMENT."

TO THE EDITOR OF ENGINEERING.

SIR,—I have read with much interest Professor Gibson's article on "Tidal Power" in your issue of December 10. I find myself, however, at issue with Professor Gibson in respect to his statement: "For a given total basin area and a given tidal range, the output is only about one-half that obtained in system (A)." This comparison is made between "the half-tide system" and "the sump system."

If one assumes a "straight-line graph" for the tide curve, the most efficient value for the fall of water in the working basin in the "sump" system (basin and sump of equal capacity) is half of the tidal range. Therefore the total power available

$$P = 18 \cdot 75R^2$$

this horse-power being expressed as *average continuous* horse-power.

The power output of the "half-tide" system is $7.5R^2$ horse-power during three hours out of every twelve, or $18 \cdot 75R^2$ continuous horse-power. That is to say the power output of the systems is identical.

Even if the two systems be assessed from the sine curve this ratio will be approximately the same. I, therefore, am unable to understand Professor Gibson's power output ratio for the two systems of 2 to 1 in favour of the half-tide system.

I have no doubt that Professor Gibson and myself are really at one in this matter; but there is at least an apparent difference of opinion between us, and I should be grateful if Professor Gibson will explain to me wherein I have misunderstood his figures.

I am, Sir, your obedient servant,

NORMAN DAVEY.

"Conaways," Ewell, Surrey.

[A proof of the above letter was sent to Prof. Gibson, who has forwarded the following reply.—ED. E.]

SIR,—I gather that Mr. Davey, in the case of a sump system, means, by the basin area, the area of the upper compartment, while I have used it as meaning the whole space occupied by both compartments, which would be available for use as the basin in the case of a simple half-tide system. In a given estuary the basin area in the latter case would be twice that in the former case, and although Mr. Davey states, the output per unit area of the upper compartment in the sump system would be the same as that per unit area of the basin in the half-tide system, the output per total area utilised would be roughly twice as great in the simple half-tide system.

Yours faithfully,

A. H. GIBSON.

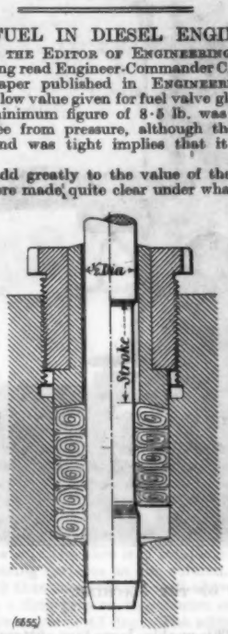
Engineering Department,
The Victoria University, Manchester.

OIL FUEL IN DIESEL ENGINES.

TO THE EDITOR OF ENGINEERING.

SIR,—Having read Engineer-Commander C. J. Hawke's interesting paper published in ENGINEERING, I was struck by the low value given for fuel valve gland friction. Surely the minimum figure of 8·5 lb. was found with the gland free from pressure, although the statement that the gland was tight implies that it was under pressure.

It would add greatly to the value of the particulars given if it were made quite clear under what conditions



(6552)

the experiment was carried out. In practice it is usual to leave the glands of both fuel pump and spray valve finger-tight, allowing the fuel to provide the necessary compression of the packing.

That this is more than sufficient is shown by the wear of the spray valve and pump plunger. The state of a pump plunger after a fair amount of running is illustrated by the enclosed sketch. The left-hand half shows the gland as packed and the right-hand half, the not uncommon state of the plunger after about a thousand to fifteen hundred hours' running. The plunger is usually very highly polished where it passes through the packing but considerably reduced in diameter. Frequently it has longitudinal scores, of a depth that necessitates re-grinding the plunger to a diameter of $\frac{1}{16}$ in. before its surface is made quite smooth.

The position taken up by the packing when under pressure was found by measurement of the length of the reduced part in conjunction with the position of the rod in the stuffing-box.

Yours faithfully,

G. URE-REID.

16, Gainsborough Mansions, Queen's Club-gardens, W.14,
17 December, 1920.

CHIMNEY DRAUGHT, STEAM BOILER PLANT.

TO THE EDITOR OF ENGINEERING.

SIR,—Some remarks on page 760, December 10, on chimney draught, provide an illustration of the use of a working formula, from an engineer's pocket-book, where a careful thinker would require an explanation from his teacher of the theory on which the numerical constants are based; accepted by the heedless without question.

We recognise as familiar the number of inches of water, 1·14, quoted in suction draught, but not always for the same height of chimney, sometimes 170 ft. or 174 ft., or furnace temperature, 600 deg. F. or 544 deg. F.

Bourne in the "Steam Engine: Ascent of Smoke and Heated Air in a Chimney," is likely to be used as an authority; and I have given the theory in my Hydrostatics, Chapter VII, page 321.

With a solid or liquid substance, where the change of volume is insensible, it is usual to work with the density, say, in pounds per cubic foot and lb./ft.²; but the reckoning is inverted into the specific volume (S.V.) in ft.³/lb., when dealing with an expansible gas where the density is small and runs in the decimal; and it is more convenient to measure the temperature, T, from absolute zero − 460 deg., instead of in F, Fahrenheit, making $T = 460 + F$.

Thus if the absolute temperature of the furnace gas is $T = 460 + F$, and of the air outside is $t = 460 + f$; and if the S.V. of the smoke inside the chimney is V, and of the air outside is v; then in the gas equation,

$$\frac{V}{v} = \frac{T}{t} = \frac{460 + F}{460 + f}.$$

At the top of the chimney the pressure in the smoke and the air is the same; and h feet lower down, at the furnace level, the pressure in the smoke will have increased by $\frac{h}{V}$, and in the air outside by $\frac{h}{v}$, lb./ft.²; so the pressure difference, of the draught, is $h\left(\frac{1}{v} - \frac{1}{V}\right)$ lb./ft.². This is measured in the gauge by z inches of water, taken of density 1,000 oz./ft., and so of S.V. 0·016 ft.³/lb., as a suction of $\frac{z}{12 \times 0 \cdot 016}$ lb./ft.²; to be equated to the draught, making

$$\frac{z}{h} = 0 \cdot 192\left(\frac{1}{v} - \frac{1}{V}\right).$$

With the barometer at 30 in., and an outside temperature of 50 deg. F., $t = 460 + 50 = 510$, dry air has S.V. $v = 12 \cdot 8$ ft.³/lb., 800 times the S.V. of water, and then—

$$\frac{z}{h} = \frac{0 \cdot 192}{12 \cdot 8}\left(1 - \frac{v}{V}\right) = \frac{3}{200}\left(1 - \frac{t}{T}\right) = \frac{3}{200}\left(1 - \frac{460 + f}{460 + f}\right)$$

In another, from the formula given in the Electricians' Pocket Book—

$$\frac{z}{h} = \frac{3 \times 510}{200}\left(\frac{1}{t} - \frac{1}{T}\right) = 7 \cdot 65\left(\frac{1}{t} - \frac{1}{T}\right)$$

where it should be recorded that temperature is reckoned from absolute zero Fahrenheit, −460.

The condition $T = 2t$ makes the flow of air up the chimney a maximum, and then

$$\frac{z}{h} = \frac{3}{400} = 0 \cdot 0075,$$

the rule given in Molesworth's Pocket Book.

With water of this standard density, a gallon is 0·16 ft.³, or 276·48 in.³, against the 277·3 of the Act of Parliament. The slight discrepancy is due to a difference of standard temperature, and also to air displacement, because the gallon is defined as the volume of 10 lb. of water at 62 deg. F., weighed in air of a standard density against brass weights.

These discrepancies are of no practical importance here, as they occur in the dishonest decimal of Perry, but they worry the careful thinker, when he finds the rival numbers appearing together, for no apparent reason. The use of a slide rule has the merit of discarding automatically these dishonest decimals.

A steel furnace is seen sometimes damped down, with the furnace door open, and a lid let down on the chimney top; in that case the air outside exerts an apparent suction on the top of the lid, calculated by the same formula; the pressure of the hot gas inside exceeds the external pressure of the air.

The smoke jack, closing the chimney over an open kitchen fire, will be working in a draught due to a pressure difference calculated in the same way.

Apply this formula to a chimney $h = 170$ ft. high, with a furnace temperature $F = 600$, $T = 1{,}060$, $t = 510$, and we find $z = 1 \cdot 32$ in., instead of 1·14 in., the number for a chimney less than 150 ft. high or else involving a liberal discount due to reduction of heat up the chimney walls. Or if we take $z = 1 \cdot 14$, and calculate the mean temperature, T, of the smoke up the chimney, we find $T = 922$, $F = 462$, a considerable drop from the furnace temperature 600, due to conduction through the walls of the chimney; and implying a temperature of the issuing smoke of only about 115 deg. F. The thick appearance of the chimney funnel in the modern steamer is due to an air casing, acting as in a thermo-flask, to reduce conduction, and so maintain the draught.

Or else, in the absence of conduction, a sustained smoke temperature of 600 deg. F. up a chimney 170 ft. high, with a suction draught of only 1·14 in. of water, would imply a very hot day, say, about 125 deg. F. in the outside air.

These are the questions the instructor must be prepared to explain, imported suddenly with the difficulties of the novice; he has to make a living in this way.

It has often been urged as an objection to mathematics that it brings out no more than was put in; but here we have been taking a result, and trying to find out what has been put in to obtain it.

The engineering triumph of skill in a steamship or locomotive contains no more steel than was dug up out of the ground, rather less, but mechanical science has fashioned the material into the useful shape.

So, too, in mathematics, the formula has fashioned the thought into a form capable of immediate application.

G. GREENHILL.

Staple Inn, December 16, 1920.

MOTOR TAXATION.

TO THE EDITOR OF ENGINEERING.

SIR,—On page 451 of your valuable issue of October 1 last is the following sentence: "The whole question of the classification of engines is, however, a very difficult one." May I hazard constructively the following comments.

Any classification should, in my opinion, leave the designer absolutely free, for instance the Treasury rating for the motor car engines, as you have pointed out favours the small-bore long-stroke quick-revolution engine, but this is certainly not in the interests of industry, and the users of such engines. Again, in my opinion, the classification should not be marred by the variation of prices of fuel, but should preferably be such that the ordinary non-technical user can ascertain costs of running, at least so far as fuel is concerned, and as it is economically sound to economise fuel and labour, I suggest that engines should be classified in accordance with maximum weight of fuel burned per hour on maximum horse-power. This may lead to a discussion in your journal, and perhaps to some assistance in an all-desirable general classification. If the horse-power at the best efficiency is stated together with the pounds of fuel per hour, I think it will be of greater usefulness.

Yours faithfully,

A. E. PARNACOTT, M.I.A.E.

December 21, 1920.

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—The members of the Institution of Automobile Engineers have placed in the hands of the Council of the Institution powers to raise the subscription of all classes of that body by 10*s.* 6*d.* per annum, or by "such other sum as the council may from time to time determine." This is placing a good deal of power in the hands of the council, much more in fact than is usual, and we are not sure that it is altogether wise. The main reason given for it, that it will obviate holding extraordinary general meetings, does not seem altogether adequate.

TRAMWAYS—FINANCE AND STATISTICS.—The White Paper relating to Tramways, Light Railways and Trackless Trolley Undertakings, formerly issued by the Board of Trade, but suspended owing to the war since the year 1913–14, has now been compiled by the Ministry of Transport, in respect of the year ended December 31, 1918, for companies, and March 31, 1919, for local authorities, and is now on sale. It shows among other points that the total capital expenditure on tramways in the United Kingdom to the end of the financial year 1918–19 was 82,842,722*l.*, an increase of 1,864,884*l.*, or 2·3 per cent., compared with the year 1913–4. The total gross receipts during the year 1918–19 were 24,635,266*l.*, and the total working expenditure 17,751,277*l.*, leaving net receipts amounting to 6,883,989*l.* It must be borne in mind that the maintenance and renewal work undertaken during the year 1918–19 was owing to war conditions, inadequate, but in spite of this the ratio of working expenses to receipts was 72·06 per cent., as compared with 64·35 per cent. in 1913–14. The number of car-miles run during 1918–19 was 9·59 per cent. less than in 1913–14, but the number of passengers carried increased by no less than 33 per cent., as shown in the following tables:—

Car-Miles Run.

	1918–19.	1913–14.	Decrease.	
	Miles.	Miles.	Miles.	Per Cent.
Local authorities	244,162,582	262,675,168	18,512,575	7·05
Companies	76,215,788	91,704,509	15,488,721	16·89
Total	320,378,376	354,379,672	34,001,296	9·59

Passengers Carried.

	1918–19.	1913–14	Increase.	
	Number.	Number.	Number.	Per Cent.
Local authorities	3,632,525,882	2,696,759,064	935,766,818	34·70
Companies	925,114,196	729,714,128	195,400,068	26·78
Total	4,557,640,078	3,426,473,192	1,131,166,886	33.01

HORIZONTAL MILLING MACHINE.

CONSTRUCTED BY MESSRS. ALFRED HERBERT, LIMITED, ENGINEERS, COVENTRY.

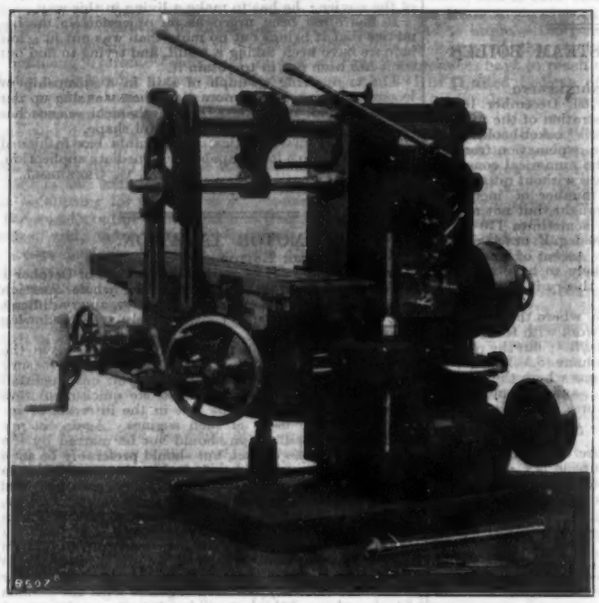


Fig. 1. Right-Hand Side of the Machine.

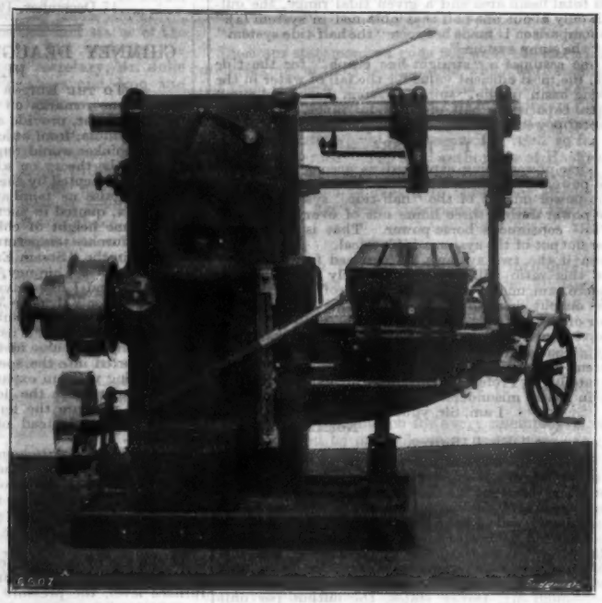


Fig. 2. Left-Hand Side of the Machine.

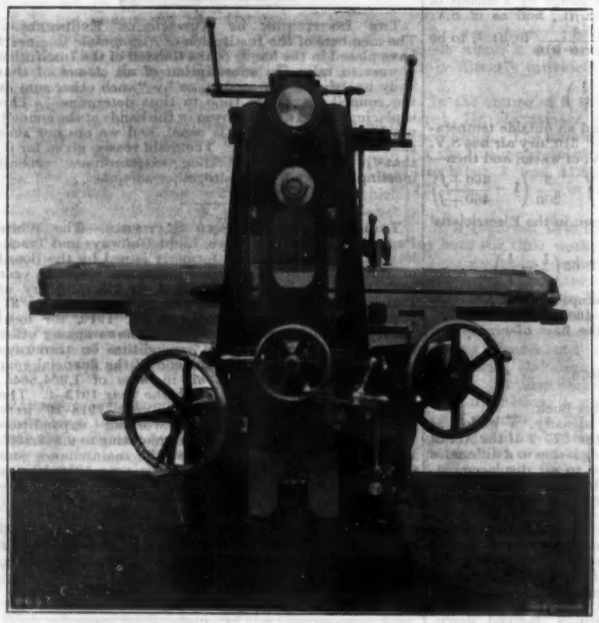


Fig. 3. View of the Front of the Machine.

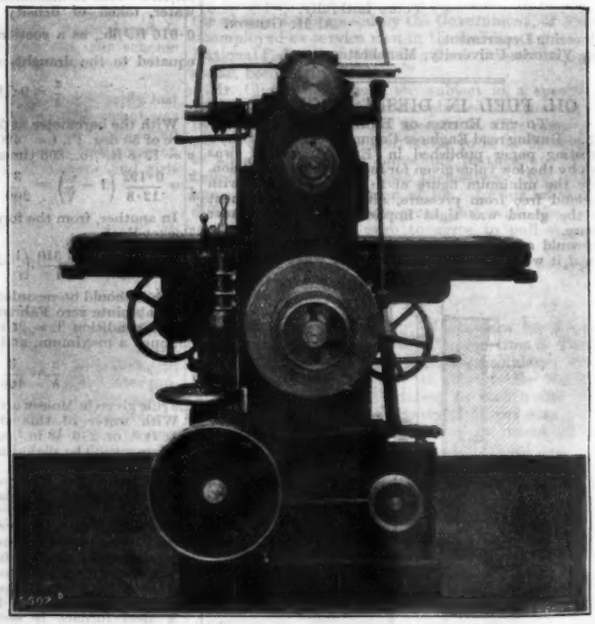


Fig. 4. Back View of the Machine.

It is a good many years since we noticed in these columns a notable horizontal milling machine brought out by Messrs. Alfred Herbert, Limited, of Coventry. The intervening time has naturally not been without its lessons, and we are now able to illustrate the latest example of this type of machine tool, recently put on the market by Messrs. Herbert. General views of the machine are shown in Figs. 1–4, on this page. Of these Fig. 1 shows the right side of the machine and Fig. 2 the left. The front is shown in Fig. 3, and a back view is given in Fig. 4. Figs. 5–8, on page 831, show details to which we shall refer shortly. The machine is known as the maker's No. 16 model, the one previously described being No. 22.

The machine is of the single pulley type, the 4 in. belt pulley being mounted on ball bearings, which are fitted to a fixed sleeve attached to the body of the machine. The clutch is engaged by the long lever extending from the top of the column towards the front, on the near side in Fig. 1. The pulley runs at 400 r.p.m. and the change box provides 16 spindle feeds, ranging from 16·4 r.p.m. to 427 r.p.m. the maximum gear ratio being 24·4 to 1. The various speeds are obtained by means of the two handles on one centre, on the side panel of the machine (Fig. 1) in combination with two crank levers just below. The third crank lever is for the spindle reverse. A speed plate showing all combinations is provided above the levers. The spindle is shown in Fig. 5, from which it will be seen to be of the box clutch type, with large taper nose. This enables large face cutters to be used and quickly centred. The nose is hardened. The cutters are held in position by the usual bolt passing right through the spindle. The feed box, placed at the base of the standard on the right-hand side, is driven by belt off the main pulley spindle. There are 18 feeds ranging from ¼ in. to 22½ in. per minute. They are all obtainable by adjustment of the dial fitted horizontal hand wheel shown above the feed box (Fig. 1). All gears on the machine are either heat-treated alloy, or of case-hardened steel, the latter having proved eminently satisfactory in service. The shafts are all of high tensile steel.

The transmission of the feed from the feed box is best seen in Fig. 1. The drive is taken to the knee

HORIZONTAL MILLING MACHINE.

CONSTRUCTED BY MESSRS. ALFRED HERBERT, LIMITED, ENGINEERS, COVENTRY.

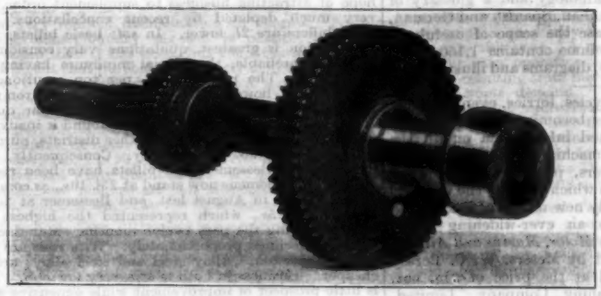


FIG. 5. THE SPINDLE WITH BOX CLUTCH NOSE.

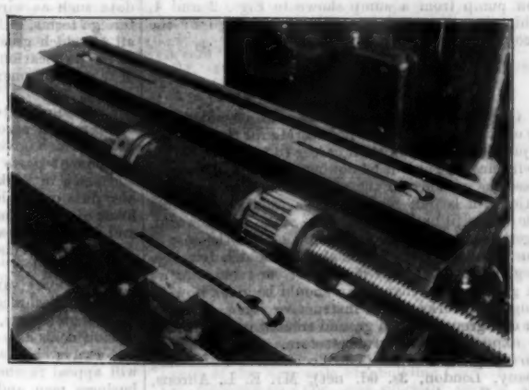


FIG. 6. THE TABLE FEED.

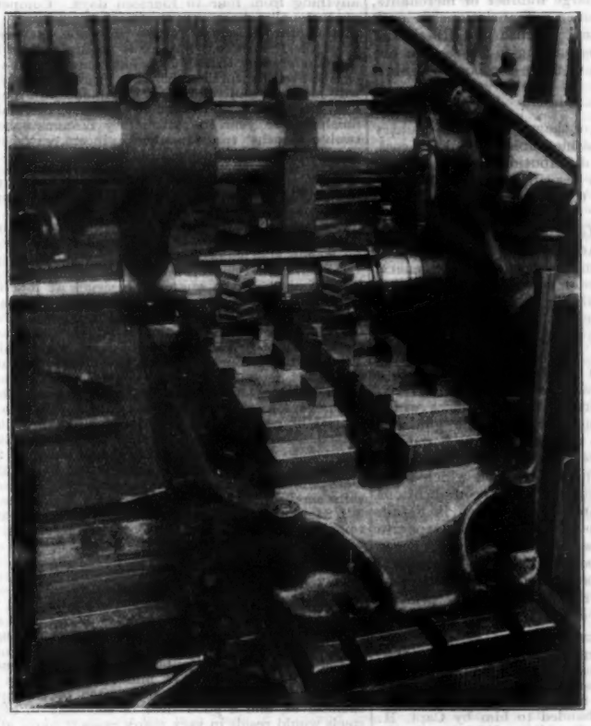


FIG. 7. GANG MILLING WITH ARBOR ROLLER STEADY.

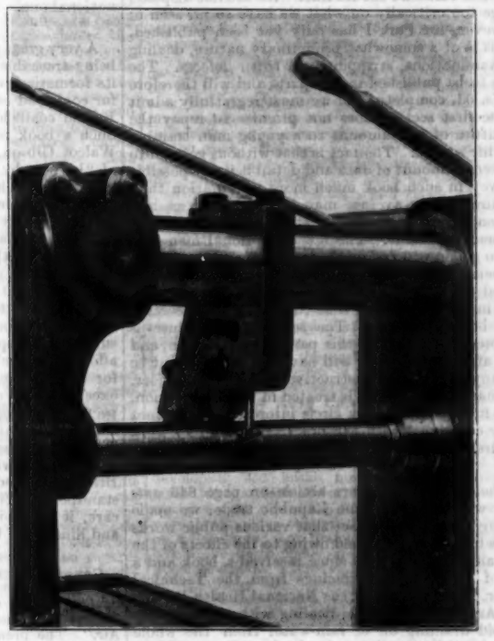


FIG. 8. ARBOR ROLLER STEADY.

by shafts and worm gearing. The gears are all enclosed and liberally lubricated. The box on the knee, which moves up and down with it on the vertical feed spindle, contains the feed reverse, which is operated by a short handle in front of the machine, seen in Fig. 3, between the centre and right hand hand-wheels. The large hand-wheels, best seen in Fig. 3, are from left to right, for the vertical hand movement of the knee, the cross traverse for the table, and the longitudinal traverse of the table. The knee is of complete box section, with long bearing surfaces on the column. It will be seen in Fig. 2 that these extend well above the saddle ways, giving a firm grip on the column on which the slides have an angle of 45 deg. The adjustable taper gibs are completely surrounded by the knee casting. The knee is clamped by the lever seen in Fig. 2, below the vertical feed hand wheel. Clamping is effected by the lengthwise movement of the taper gib by rack and pinion. The saddle is carried on the knee on very wide surfaces with a narrow guide strip, which may just be seen in Fig. 6, which gives a view of the saddle bearing for the table. The table is of the flush top type and is carried in a long saddle bearing, being driven by spur gears from the feed shaft. The table feed screw is stationary and the length of the bronze nut is more than 10 diameters of the screw. This nut is driven by the small spur gear shown, instead of by the bevels frequently adopted. The nut has adjustment for wear, being made in two parts, which can be set away from one another along the screw. A ball thrust washer is fitted. The table slides are lubricated by oiling rollers as shown in Fig. 6; the slots extending from the roller cavities carry oil to holes running down to the saddle bearing on the knee below. The method of engaging the feed is by dropping worm, used on this firm's machines for many years, the worm moving out of engagement as soon as the feed is tripped. The vertical feed from centre of the spindle is from 1 in. to 20 in. The table which is 55 in. by 13¾ in., has a longitudinal feed of 34 in., and cross traverse of 13¼ in., the maximum width from the face of the column to the arm brace being 27½ in.

It may be pointed out that after the spindle speed and the feed has been set, all movements can be controlled from the front of the machine (Fig. 3). We have already indicated most of these controls, but may mention further that the vertical or cross traverse power movements are obtained by the small horizontal lever to the left of the cross traverse hand-wheel, in conjunction with a selector lever to the right of the same wheel (Fig. 3). The several motions are fitted with trips, which may be seen in Figs. 1, 2, and 3. The elevating movement, which is by telescopic screw, is, in the case of the hand motion, by hand wheel and crank, the latter remaining idle when this movement is being made by power, thus obviating risk of injury to the operator.

The overhead arm is 4½ in. in diameter and is centred 8¼ in. above the spindle centre. It is clamped in position by a bolt at the back end of the column, and by the second long upper lever projecting towards the front of the machine. The arm is very strongly braced to the knee, by a double clamp which is well seen in Figs. 1 and 3. The arm is provided with a stiff arbor steady. In Figs. 7 and 8 we give illustrations of an interesting adaptation of the roller steady to this class of work. This steady is extremely valuable in cases of gang milling such as that shown, giving a very good intermediate support to the long arbor which it is impossible to secure in any other way, where clearance is very small below the arbor. The steady is provided with a small wiper to clean and lubricate the surface of the arbor revolving under the rollers. The work shown in Fig. 7 is the gang milling of tool posts between two gangs of cutters. If the ordinary support had been used between the cutters the latter would have had to be increased in diameter at least 1½ in. The side slot is machined in one cut, the depth being ½ in. and the width of the double cut 4½ in., with a feed of 1½ in. per minute. The cutters are of the interlocked type, of opposite spirals, giving positive rake on the side teeth, thus producing a very clean finish.

The shafts of the machine are under continuous

cascade lubrication, by pump, a mica inspection window above the change speed levers affording the operator ready means of assuring himself that the system is working normally. This is seen in Fig. 1. The cutting medium is supplied to the cutters by a small belt-driven pump from a sump shown in Figs. 2 and 4, to which it is returned from the table trough by the telescopic pipe shown in Fig. 2.

NOTES ON NEW BOOKS.

In these days of heavy expenses we consider that every effort should be made in catering for the younger men just entering upon their career to meet the length of their purse. There is no doubt that the unavoidable increase for instance in the subscriptions to technical societies will be felt severely by a number of young people who still have their way to make in the world. The general tendency at the same time for the cost of technical books to increase is also to the disadvantage of beginners. Although it is quite unavoidable, we think greater care than ever should be given now to making such works of real instructive value, covering either new ground, or old ground treated in some much more explicit way than heretofore. The author of *Repairing of Locomotives* (The Locomotive Publishing Company, London, 3s. 6d. net), Mr. E. L. Ahrons, M.I.Mech.E., in his preface to this book, claims that he is covering new ground, but we are not altogether certain that his volume is going to be of the high instructional value we should like. We are not disposed to judge too critically on what we have so far seen of it, however, for Part I has only yet been published, and this is of a somewhat preliminary nature, dealing with examinations, stripping and boiler defects. The work is to be published in five parts and will therefore cost 17s. 6d. complete, and we must regretfully admit that the first section does not promise to repay the expenditure of this amount to a young man training for his life's work. The fact is that without going into an immense amount of data and detail it is not possible to convey in such book much more information than is acquired by an average man in his apprenticeship, and then only in a sketchy manner of comparatively little practical value. The few exceptional men who mean to get on will find methods of going much further, and their note books or the knowledge practically acquired and stored away in their minds, would soon exceed in value, we fear, that contained in the section of the book before us. The school of experince is undoubtedly the best in this particular direction, and we are afraid the author will have his task cut out to make anything really instructive out of his subject, in the manner in which it is treated in this first section, though it may appeal to a circle interested in, but not directly concerned with the practical every day work of repairs.

In the course of a short article on page 646 *ante* dealing with the Argentine Republic trade, we made a passing remark to the fact that various public works schemes had been postponed owing to the effects of the European war. We have since received a book and a series of 31 plans and tracings from the Technical Director, Buenos Aires, of the National Health Bureau of the Argentine Republic, dealing with a scheme for the rapid draining off of rain-water from the whole area occupied by the city and suburbs of Buenos Aires, thus preventing the inundations which frequently occur in the districts which lie at a comparatively low level. The book is entitled "*Proyecto de Desagües de Aguas Pluviales.*" The scheme is a very complete one; it comprises the closing-in by culverts of two rivers, the construction of a large series of conduits, catch drains, &c., and bridge work for shifting existing railway lines. Three tenders were sent in, and the one showing a total expenditure of pesos 113,978,094 was accepted. Reinforced concrete is to be used extensively for the whole work.

All who are interested directly or indirectly in wireless telegraphy will find a large amount of information in "*The Year Book of Wireless Telegraphy and Telephony*," which is issued at the price of 10s. 6d. by The Wireless Press, Limited, 12 and 13, Henrietta-street, Strand, W.C. 2. A very short chapter to be found at the close of the book deals with "Amateurism in Wireless Telegraphy," and states the following: "There can be no shadow of doubt that we owe mainly to the amateur the rapid development of wireless telegraphy during the late war. Little stations, dotted about all over the country and in many cases equipped with nothing more pretentious than home-made apparatus, taught all concerned a number of very valuable lessons." We are glad to read this tribute paid to the efforts made by skilful outsiders, and feel confident that their work will lead to still further progress in this particular branch of science. The book contains the laws and regulations on wireless telegraphy enacted by the various nations of the world; a list of the numerous land stations and ship stations in every country, with particulars concerning them; chapters on radio-communication and meteorology; on different apparatus, patents, &c.; a large amount of useful data such as wireless terminology and a glossary of foreign terms, in French, Italian, Spanish and German, all of which greatly increase the scope of usefulness of the publication. The volume contains 1,150 pages of text and numerous maps, diagrams and illustrations.

The use of motor cars, cycles, lorries, even of motor scooters and aeroplanes, is becoming so general that books which give illustrated information on all the component parts of such machines, the names and addresses of makers, powers, prices where possible, also data on the legislation which governs the employment of these comparatively new means of locomotion and transport, appeal to an ever-widening circle. A book of this class is "*The Motor, Marine and Aircraft Red Book*, 1920," compiled by Messrs. W. C. Bersey and A. Dorey, and issued at the price of 21s. net, by the Technical Publishing Company, Limited, 1, Gough-square, Fleet-street, E.C. 4. A special section deals also with marine motors, Diesel engines, waterways and harbours of the United Kingdom, and will appeal further to a large number of merchants, business men and yachtsmen. Translations in each section into French, Italian, Spanish and Russian of the technical terms corresponding to the section are greatly welcome and help to make the book an international one.

A very great proportion of the wealth of this country being traceable to our coal measures, a book on coal, its formation, origin and distribution, on prospecting for coal, and containing a description of the different British coalfields, is sure to appeal to a wide circle. Such a book is entitled "*Coal in Great Britain*," by Walcot Gibson, D.Sc., F.G.S., published at the price of 21s. net, by Edward Arnold, 41 and 43, Maddox-street, W. It has been compiled primarily as a general guide for mining engineers, mine owners and mining students, but it is certain also to prove both interesting and useful to a wide circle of the British public who are not, directly, at all events, concerned with coal getting. The varieties in which coal is found, from that of recent formation down to anthracite, are reviewed and the characteristics of each are entered into. The remarks concerning the difficulties which surround prospecting, concerning also the guidance afforded by the fossils met with in the cores bored out for determining the layers encountered, give an excellent idea of the complications with which prospecting for coal is surrounded. The complications due to folds and faults are also described in detail. The greater part of the book is divided into separate chapters covering each separate coalfield of Great Britain, treated more especially from the geological standpoint. The book has been compiled with great care, it is interestingly written, and clearly printed, and illustrated by maps, sections and views of fossils.

Crystal Palace Engineering Society.—The "Wilson Premium" for the best paper read before this Society during the past session, has been awarded to Mr. F. R. Alderman, for his paper on "Compressed Air." The premium was handed to him by Capt. H. Riall Sankey, C.B., C.B.E., President of the Institution of Mechanical Engineers, on the occasion of the 144th certificate distribution at the Crystal Palace School of Practical Engineering, at which he presided on Dec. 20.

Electrification of Central of Brazil Railway.—According to a cable received by the Department of Overseas Trade from the Commercial Secretary to H.M. Embassy in Rio de Janeiro, Congress have authorised the expenditure of 60,000 contos (at present exchange, approximately 2,900,000*l.*) on the electrification of the Central of Brazil Railway, which is owned and operated by the Brazilian Government. United Kingdom firms requiring further particulars are recommended to get into touch with the Commercial Secretary to H.M. Embassy, Rio de Janeiro.

Central Hot Water Supply and Heating.—The Henry Saxon Snell prize of the Royal Sanitary Institute was founded to encourage improvements in the construction, or adaptation, of sanitary appliances, and is awarded by the Council of the Institute at intervals of three years. Next year the prize will consist of fifty guineas and the medal of the Institute, and it is offered for an essay containing "Suggestions for a System of Central Hot Water Supply and Heating adapted to Modern Housing Schemes and to Existing Groups of Houses." The points to be dealt with include central installation, appliances for and methods of distribution, methods of conserving heat, provision for continued supply during repairs, cost, and combination with other services for reducing expenses. Essays must not be longer than 5,000 words and must be delivered before August 31, 1921; but full conditions of other conditions to be complied with can be obtained from the Secretary of the Royal Sanitary Institute, 90, Buckingham Palace-road, London, S.W. 1.

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

Iron and Steel.—Steel production has been further restricted to meet the general fall in the demand. Despite this, the downward trend of prices continues in the hope of attracting business to supplement order books very much depleted by recent cancellations. Hard basic billets are 2*l.* lower. In soft basic billets, where competition is greatest, quotations vary considerably, and are unreliable, the official minimum having been withdrawn. The price of 20*l.* per ton mentioned by some makers, however, is still 5*l.* or more per ton above the quotation for foreign material of similar quality. Makers of better quality steels have found it inadvisable longer to ignore movements in other districts, purchases having fallen so considerably. Consequently, both Siemens and Bessemer acid billets have been reduced 2*l.* per ton. Siemens now stand at 25*l.* 10*s.*, as compared with 28*l.* 10*s.* in August last, and Bessemer at 26*l.*, as against 28*l.* 5*s.*, which represented the highest level reached during the past twelve months. Manufactured steel has declined proportionately. Wire rods are down 2*l.* to 6*l.* per ton. Alloy steel and steel alloys are also cheaper. Business in both is at a very low ebb. There is little prospect of improvement while expensive stocks remain. No change can be reported in the engineering section. Short-time employment is ample to furnish the production required for the comparatively few remaining contracts. Establishments will be closed anything from four to fourteen days. Competition is exceptionally keen in electrical machinery, for the manufacture of which special provision has been made since the Armistice. Failure to secure several big contracts offered by British users has concentrated attention on the need for further economy in manufacture. Railway material and rolling stock branches are moderately busy on English and Colonial orders. Tool makers are finishing the year in satisfactory circumstances. The twelve months' trade in pliers, pincers, saws, files and rasps, has been exceptionally good.

South Yorkshire Coal Trade.—Merchants are exceptionally busy dealing with a belated demand for Christmas supplies. Failure to place orders till the last few days before the pit stoppage may result in many households going short. Collieries are badly hampered by wagon shortage, due in part to weather conditions. The position in regard to small fuel has been strengthened by the necessity to augment reserves at pits to meet week-end and new year requirements. Coalowners complain of the damaging effect of restriction of exports. On the other hand, Continental buyers are questioning the quality of fuel sent to them, even at reduced prices. Manufacturing consumption, both in the cotton and steel industries, is much lower, but this is counterbalanced by the need for augmenting reserves against the Christmas stoppage. Inland works are taking the whole of the output of gas fuels. Quotations: Best branch hand-picked, 37*s.* 2*d.* to 38*s.* 2*d.*; Barnsley best silkstones, 37*s.* 2*d.* to 37*s.* 8*d.*; Derbyshire best brights, 35*s.* 2*d.* to 36*s.* 2*d.*; Derbyshire house coal, 32*s.* 8*d.* to 33*s.* 2*d.*; Derbyshire best large nuts, 32*s.* 8*d.* to 33*s.* 8*d.*; Derbyshire small nuts, 31*s.* 8*d.* to 32*s.* 8*d.*; Yorkshire hards, 32*s.* 8*d.* to 33*s.* 8*d.*; Derbyshire hards, 32*s.* 8*d.* to 33*s.* 8*d.*; rough slacks, 28*s.* 2*d.* to 29*s.* 2*d.*; nutty, 27*s.* 2*d.* to 28*s.* 2*d.*; smalls, 23*s.* 2*d.* to 24*s.* 2*d.*

Heat Treatment of Mining Drills.—Messrs. Automatic and Electric Furnaces, Limited, 281 to 283, Gray's Inn-road, W.C. 1, have recently issued a small Bulletin, No. 26, on the heat treatment of mining drills. This is written by Mr. E. A. Wraight, A.R.S.M., M.I.M.M., and will be found a practical little pamphlet. The treatment of drills at mines is very often a very haphazard affair, in the hands often of the operators themselves, and a good deal of economy in expensive steels would result in very many cases if more attention were given to this matter. It is, of course, too much to expect that expensive apparatus should be provided at every small mine, but in other cases the saving and the improvement of the work would soon offset the cost of introducing method and system into this operation.

Ferro-Concrete Lock Gates.—A paper entitled "Special Application of Reinforced Concrete in Docks," containing an interesting account of some reinforced concrete lock gates at Tilbury Docks, was read before the Concrete Institute on Thursday, the 16th instant, by Mr. H. J. Deane, B.E., M.Inst.C.E., The gates, which are used to close the entrance from an extension of the main dock to a dry dock used in the construction of ferro-concrete ships, barges and other vessels, have a total width of 40 ft., and a height of 13 ft. 8 in. The sill is segmental in plan with a radius of 26 ft. 4½ in. Each leaf consists of a slab 3½ in. thick with double horizontal and vertical reinforcement composed of ¾ in. rods spaced 6 in. apart, and there are four horizontal stiffening ribs extending over the whole width, and a vertical rib at the centre of the leaf is introduced between the horizontals. The top horizontal rib was made 2 ft. wide to form a gangway across the lock and the reinforcement of this rib is composed of ¾ in. rods with ½ in. stirrups placed on 4 in. centres. The two horizontal ribs are 12 in. by 5 in. in section, doubly reinforced with ¾ in. rods and ½ in. stirrups on 6 in. centres, while the bottom rib is 12 in. wide and tapers from 6½ in. to 5 in. in depth. The drawings were prepared by Messrs. Christiani & Nielsen, and were approved by the Chief Engineer of the Port of London Authority. The construction of the gates, which occupied about twelve weeks, was completed on January 5 of last year, and the first five reinforced concrete barges were floated out of the dock on May 1, 1919.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Usually business is quiet at this season of the year, and on the present occasion, in addition to the customary holiday spirit, there is a feeling that a general slump is approaching, and traders show very marked disinclination to operate. Scarcity of Cleveland foundry pig-iron is possibly somewhat less acute than it has been, but the situation continues so stringent that purchasing for early delivery is a matter of very great difficulty. Extensive forward business could be placed at current rates, but buyers will not commit themselves ahead. Removal of the embargo on export of foundry pig has not been followed by any Continental demand for that commodity. To home customers No. 1 is 237*s.* 6*d.*; and No. 3 is 225*s.* Forge, mottled and white qualities are very plentiful and slow of sale, but makers are not disposed to lower their figure, and still ask 225*s.* for these descriptions.

Hematite.—Very little news is ascertainable concerning East Coast hematite. Supply is apparently better, and both makers and merchants are offering fair parcels for practically any delivery, but customers are shy. There is no inquiry from abroad. For home consumption No. 1 is 262*s.* 6*d.*, and mixed Nos. are 260*s.*

Foreign Ore.—Business in foreign ore is dead idle. Consumers continue to carry considerable stocks, and they are off the market altogether just now. The outside ex-ship Tees quotation for rubio, of 50 per cent. quality, is 49*s.*

Coke.—Local consumers of coke now that they have fairly good stocks and supplies are plentiful, look for a fall in prices, but, as yet they have still to pay 62*s.* 9*d.* at the ovens for average blast-furnace kind, and 65*s.* 3*d.* at the ovens for quality low in phosphorus.

Manufactured Iron and Steel.—Transactions in manufactured iron and steel are not heard of, but quotations are to be revised early in the new year, and this may lead to resumption of business to some extent. Some producers are closing down for a rather longer period than is usually taken for the Christmas holidays. Common iron bars are 27*l.* 10*s.*; steel ship, bridge and tank plates, 24*l.* 10*s.*; steel ship angles, 24*l.*; steel boiler plates 31*l.*; steel joists, 24*l.*; channels and flats, 24*l.* 5*s.*; rounds and squares, 26*l.* 10*s.*; soft billets, 22*l.*; medium billets, 23*l.*; hard billets, 24*l.*; heavy sections of steel rails, 25*l.*; fish-plates, 30*l.*; black sheets, 28*l.*; and corrugated galvanised sheets, 30*l.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—The depressed state which has recently been very noticeable in the Scotch steel trade shows no sign of passing off, and it is even getting more intense. Old orders have been the means of keeping the mills going fairly steadily up till now, and there is still quite a respectable tonnage to be turned out yet, but forward booking is almost at a standstill. Buyers all round seem most determined to hold off meantime, and only urgent business is being put forward. They are thoroughly convinced that a substantial fall in prices is most probable very soon, hence their keeping out of the market at present. The demand for plates is fairly good still, but structural sections are extremely quiet and little business is passing. Black sheet makers have not booked much fresh business of late, and it remains to be seen whether or not the consumers are content with the amount of the recent reduction. All branches of the steel industry are feeling the easier tendency of general trade, and exporting is on a very small scale.

Malleable Iron Trade.—Little change of any kind has taken place in the bar iron trade of Scotland over the week, and although works are moving along tolerably satisfactorily the future is not too reassuring. Buyers are not rushing in with large orders because prices are down—rather are they going warily and booking only as much as will suffice for the present, being of opinion that the New Year will bring with it still lower quotations.

Scotch Pig-Iron Trade.—The prevailing note in the pig-iron trade of Scotland is still the scarcity of almost all grades of iron. Foundry iron is in much request, while the demand for hematite is also exceedingly large. The total output is readily taken up by the home customers, and shipping is really a negligible quantity at the moment. When the full number of furnaces are put into blast the output will be considerably increased and export may receive more attention. Prices are easier inclined.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—Depression has been the chief characteristic of the coal trade in the past week. Taken in a general sense there is no coal market. The demand is limited, as foreign buyers are adopting a hold-off policy anticipating a further fall in prices, while the action of the Bureau des Charbons in fixing maximum import prices at many shillings below current market values has brought new business to an almost complete standstill. It is reported, however, that an important colliery undertaking has concluded a contract to supply French buyers with a 1,000,000 tons of large and small coal over next year at 70*s.* per ton f.o.b. for large, and 50*s.* for smalls. The statement must, however, be accepted with reserve, in view of the Bureau des Charbons decision to revise import prices for February and succeeding months as the present schedule only applies to January delivery. Current prices are many shillings per ton below those of a week ago. They are irregular and entirely dependent on the individual circumstances of buyer and seller. Best large steam coals which were quoted at 105*s.* last week, have been sold down to 90*s.*, and Monmouthshire at 80*s.* against 95*s.*, while inferior qualities are practically without demand and range from 70*s.* for large and 45*s.* for smalls with throughs round 50*s.* Foreign cargo exports in the past week at 358,000 tons have only been exceeded on five previous occasions this year. A new allocation scheme has been brought into operation in view of the changed conditions resulting from increased output and a slackening in the home demand. A "basis output" has been fixed for each individual colliery, determined by the average output in the six weeks ended September 25. Collieries whose production exceeds the basis output are entitled to apply for extra output permits, which will be granted if the District Committee are satisfied that the home demand is being fully met.

The Iron and Steel Trades.—The outlook in the tin-plate trade is very gloomy. Messrs. Richard Thomas & Co., Limited, one of the largest tinplate manufacturers in South Wales, have informed their employees that owing to the depression, they have no alternative but to close their works at the expiration of the notices which are now running out, and terminate at the end of the month. Five works in Llanelly will be affected and nearly 5,000 men will be thrown out of employment. The demand is very quiet, and makers are now offering supplies at 39*s.* per box, with buyers' ideas round 35*s.* 6*d.*

WATER POWER IN THE DUTCH EAST INDIES.—We learn from an article in a recent number of *Sluyters' Monthly East Indian Magazine* that the water-power resources of the Dutch East Indian Islands are being studied with a view to the future electrification of the State Railways, and also for the purpose of supplying energy for the development of the industries of the islands. It appears from a rough estimate that the minimum water power available in Java, Sumatra, North Borneo and Celebes together, amounts to 5,500,000 horse-power, and that the regions containing the most water power are West Java, North Sumatra, Central Borneo, and the lake territory of Central Celebes. The utilisation of water power is, however, most developed in West Java, where a number of hydro-electric power stations are now under construction for supplying power for the Prisk-Batavia-Buitenborg electric railways, and for the general supply of electric energy to Batavia and its suburbs, as well as to Buitenborg and Bandoeng, and to the neighbourhood of the wireless station at Malabar. In the other districts mentioned, some power plants are in existence, and others are in course of construction, while careful investigations are being made with a view to future developments.

SHIPBUILDING AND SHIPPING.—In a thoughtful and suggestive paper read before the North-East Coast Institution of Engineers on the 17th instant, Mr. Maxwell Ballard analysed the relationship between shipbuilding production, prices and the freight market. He pointed out that the outstanding feature of the position to-day is the absence of any consistent relationship between tonnage supply, the price of tonnage, and the freight markets. In shipping, he said, although freights are high, vessels find it extremely difficult to pay their way, and in shipbuilding, while the yards are filled with work, and trade is apparently in full swing, the outlook is one of great anxiety. The condition, however, he regards as purely temporary, since a great expansion of world trade must follow the period of stagnation in production and destruction of capital during the war. In the not-far-distant future he expects a restoration of good trade accompanied by the vast carrying of freights, but he points out that this cannot be achieved until stabilised conditions rule. We have not space to deal here with the arguments on which this conclusion is based, but the latter is certainly of sufficient interest to record, and the paper itself is worthy of careful perusal by all students of shipping economics.

AEROPLANE STRESS ANALYSIS.—Report No. 82, issued by the United States National Advisory Committee for Aeronautics is a handbook of aeroplane stress analysis prepared in 1917 for the Chief Constructor of the United States Navy, Admiral D. W. Taylor, and it was primarily intended as a guide for persons who had to make estimates of aeroplane stresses and factors of safety for the United States Government. The text, written by Dr. A. F. Zahm, comprises three parts: Part I, being introductory, presents briefly the mechanics of materials and of elementary structural members; Part II treats of aeroplane wing stresses; Part III treats of body stresses. The text is followed by Part IV, written by Mr. L. H. Crook, which gives in detail the numerical solutions of the illustrative practical problems presented in the text, by use of the methods and equations therein formulated. Finally, in Part V, prepared by the authors jointly, are assembled the tables, formulæ, and descriptive diagrams illustrating the text; also the graphical solutions of many of the standard stress problems given. The whole work, comprising 70 pages, is compact and orderly, with only brief arguments or explanations. It assumes that the reader has had an average engineer's training in the mechanics of materials and elementary structures. A copy of Report may be obtained upon request from the National Advisory Committee for Aeronautics, Washington, D.C., U.S.A.

NOTICES OF MEETINGS.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, December 31, at Caxton Hall, at 8 p.m. Lecturette on "Drying Plant," by F. A. Alliott, A.M.I.Mech.E. (Member).

ROYAL INSTITUTION OF GREAT BRITAIN.—Christmas Lectures: "The Haunts of Life," by Professor J. Arthur Thomson, M.A., LL.D., Thursday, December 30, at 3 p.m. Lecture I, "The School of the Shore"; Saturday, January 1, 1921, Lecture II, "The Open Sea."

THE INSTITUTION OF ELECTRICAL ENGINEERS' BENEVOLENT FUND.—The council of the Institution of Electrical Engineers have received from Mr. E. M. Hughman, of Bombay, an offer of a donation of £250 to the Benevolent Fund of the Institution, on condition that nineteen similar donations are received before March 31, 1921. The committee of management of the fund earnestly hope that the nineteen donations specified will be forthcoming as the fund will thereby be benefitted to the extent of 5,000*l.* All communications should be addressed to the secretary of the Institution at 1, Albemarle-street, London, W.1.

NEW SHIPYARD ON THE TYNE.—An event of considerable interest in connection with shipbuilding on the North-East Coast occurred yesterday, when the new yard of the Newcastle Shipbuilding Company, Limited, at Hebburn-on-Tyne, was officially opened by Rear-Admiral Sir Edward F. Inglefield, K.B.E. On the same day the company's first vessel, the ss. Zabaldine, building for the Compañia Maritima Bilbao, was launched from the yard, the construction of the vessel having proceeded simultaneously with the development of the yard. A reference to the latter was made on page 498 of our last volume, but we may mention that it now includes three barge berths, four berths for vessels of 4,000 tons deadweight, and three berths capable of taking ships up to 10,250 tons deadweight. We understand, however, that it is proposed to change the line of one of the present 4,000-ton berths to enable it to be lengthened sufficiently to accommodate an additional vessel of 10,250 tons. Besides the vessel just launched, three vessels of 4,150 tons deadweight are building at the yard for Norwegian owners, and three oil tankers of 10,250 tons deadweight have been laid down on the largest berths. In general, it may be stated that the yard has been laid out for the purpose of specialising in oil-tanker work, and the staff has been selected with the same object in view.

THE NAPIER AERO ENGINE.—We are informed that Messrs. D. Napier & Son, Limited, have recently carried out a number of exceptionally severe trials of one of their 450 h.p. aero engines. The engine was first put through a series of six runs, the aggregate duration of which was 50 hours. The longest of these runs extended for 12 hours, during which the engine developed 383·5 brake horse-power at 2,018 r.p.m. In the other five runs, which varied from 5 hours to 10 hours in length, the powers and speeds were about the same. After completing these tests the engine was subjected to a high-speed test, in which it was run for one hour at 2,300 r.p.m., developing 352 brake horse-power, and immediately after this four high-power tests, each one hour in length, were carried out. The following powers and speeds were developed in these tests:—454·5 brake horse-power at 2,100 r.p.m., 457 brake horse-power at 2,015 r.p.m., 531 brake horse-power at 2,225 r.p.m., and 490 brake horse-power at 2,026 r.p.m. The run for one hour at 531 brake horse-power and at 2,225 r.p.m, should be particularly noted, as it is certainly an excellent performance for an engine of which the normal output is 450 brake horse-power, and the normal speed 2,000 r.p.m. In all other respects the trial results are eloquent testimony to the reliability of the engine—a feature of primary importance in civil aviation. We illustrated and described the design and construction of the Napier engine in our issue of July 23 last on page 106.

THE PHYSICAL SOCIETY AND OPTICAL SOCIETY'S ANNUAL EXHIBITION.—This exhibition, which is to be held on Wednesday and Thursday, January 5 and 6, 1921, at the Imperial College of Science, South Kensington, will be open in both the afternoon (from 3 to 6 p.m.), and in the evening (from 7 to 10 p.m.). Sir W. H. Bragg, K.B.E., F.R.S., will give a discourse on "Sounds in Nature," at 4 p.m., on January 5. Emeritus Professor Archibald Barr, D.Sc., LL.D., will give a discourse on "The Optophone—an Instrument which enables the totally blind to read ordinary print," at 8 p.m., on January 5, and at 4 p.m., on January 6. After the discourse a demonstration will be given by a totally blind person. At 8 p.m., on January 6, Prof. C. R. Darling will give a discourse on "Some Unusual Surface Tension Phenomena." All the lectures will be illustrated by experiments. About 50 firms will be exhibiting and a number of experimental demonstrations have been arranged. We understand that invitations have been given to the Institution of Electrical Engineers, the Institution of Mechanical Engineers, the Chemical Society, the Faraday Society, the Wireless Society of London, and the Röntgen Society. Admission in all cases will be by ticket only, and Members of the societies just mentioned desiring to attend the Exhibition, should apply to the Secretary of the Society to which they belong. Others interested should apply direct to F. E. Smith, F.R.S., hon. secretary of the Physical Society, National Physical Laboratory, Teddington, S.W.

2,700-B.H.P. DOXFORD DIESEL ENGINE.

CONSTRUCTED BY MESSRS. WILLIAM DOXFORD AND SONS, LIMITED, ENGINEERS, SUNDERLAND.

(For Description, see Page 845.)

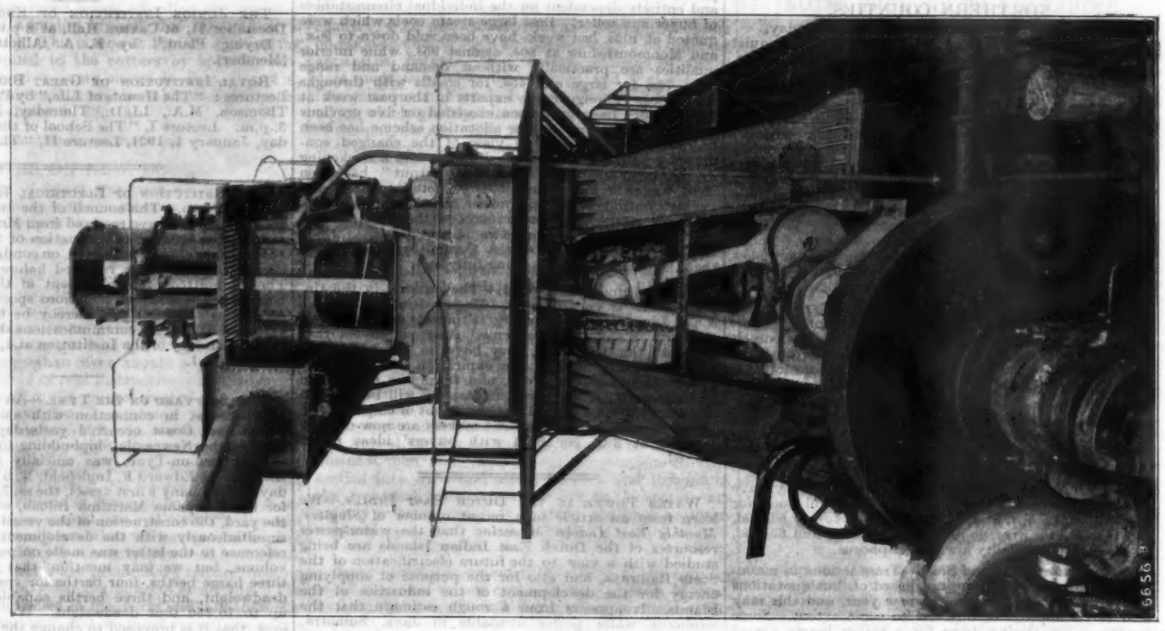


Fig. 2.

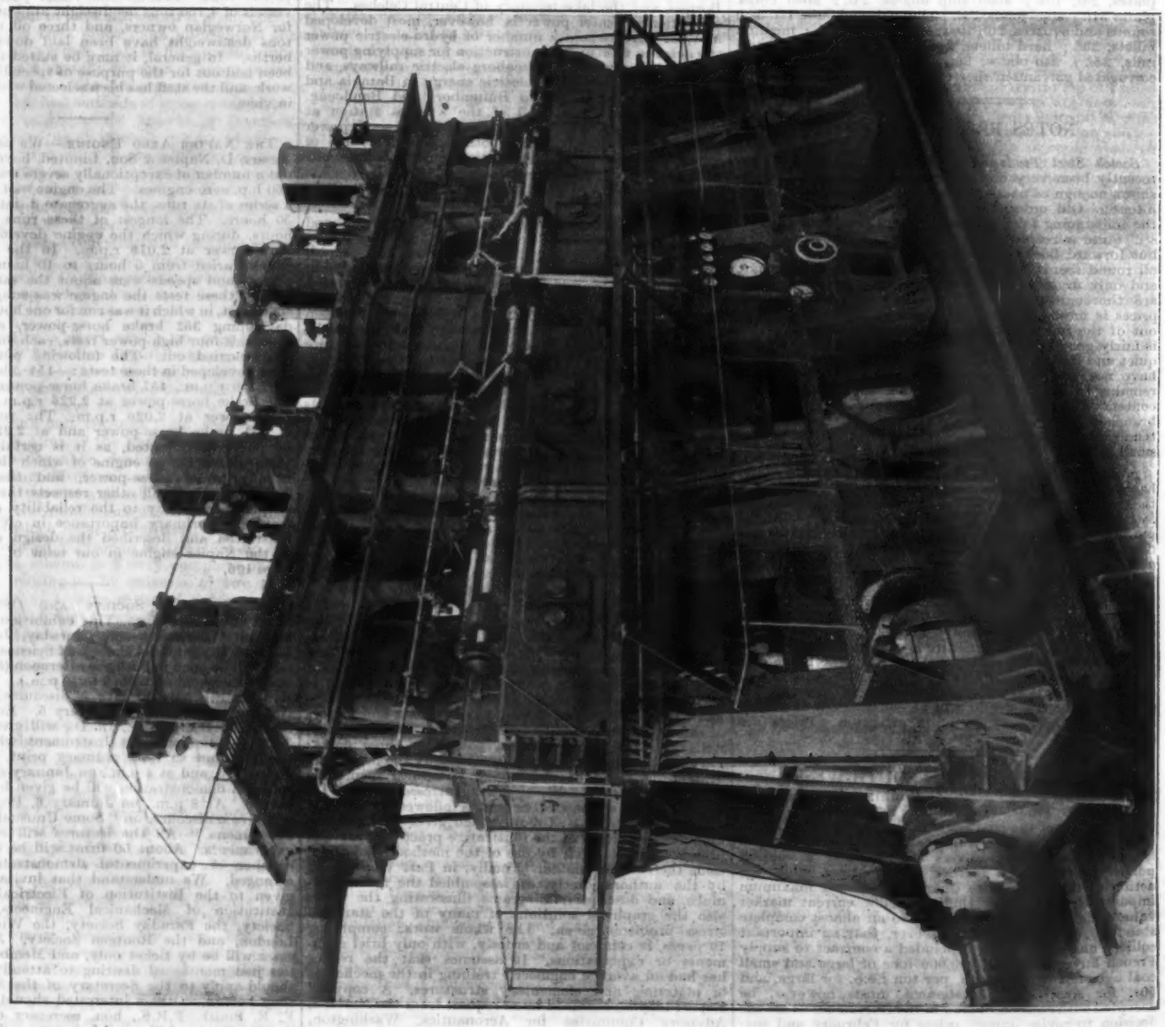


Fig. 1.

TWIN-SCREW TURBINE DRIVEN

CONSTRUCTED BY MESSRS. YARROW AND CO., LIMITED, ENGINEERS

(For Description see Page

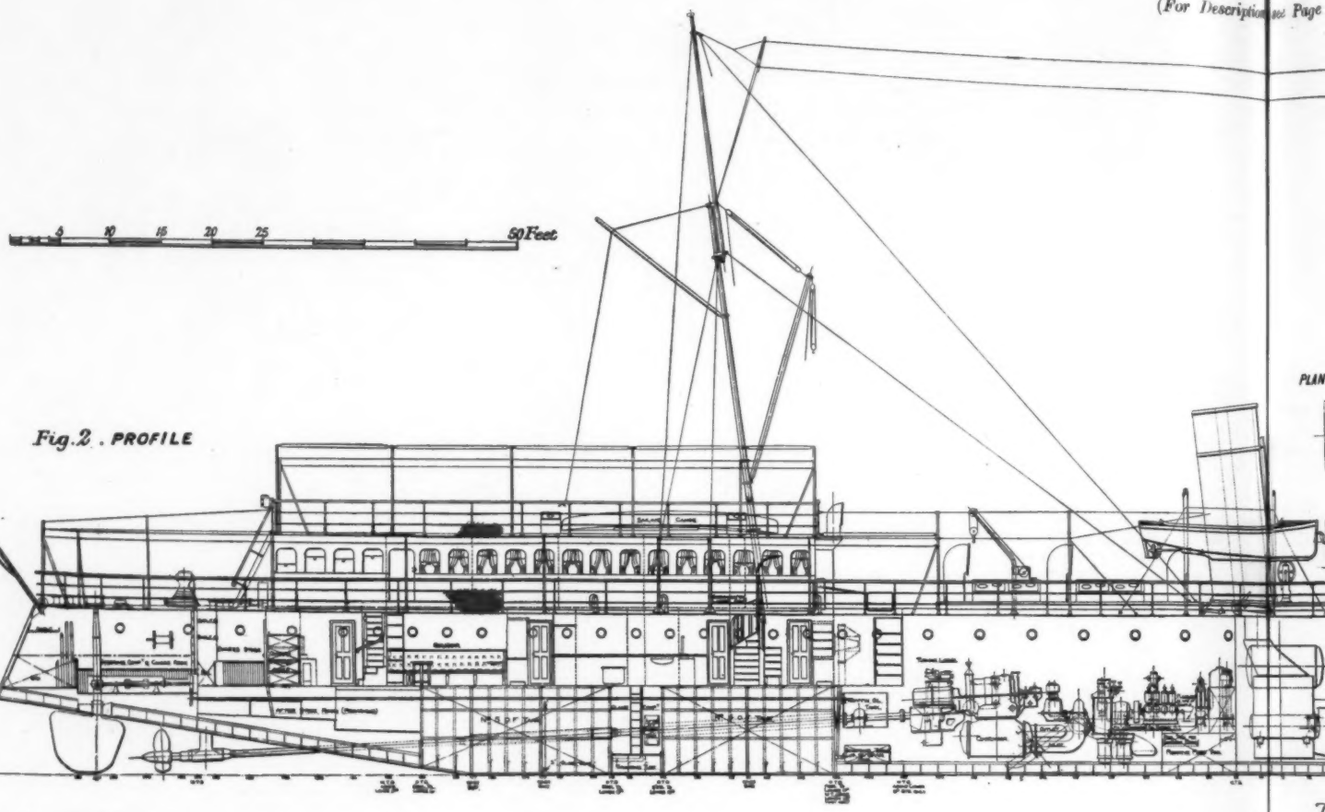


Fig. 2. PROFILE

Fig. 3. UPPER DECK

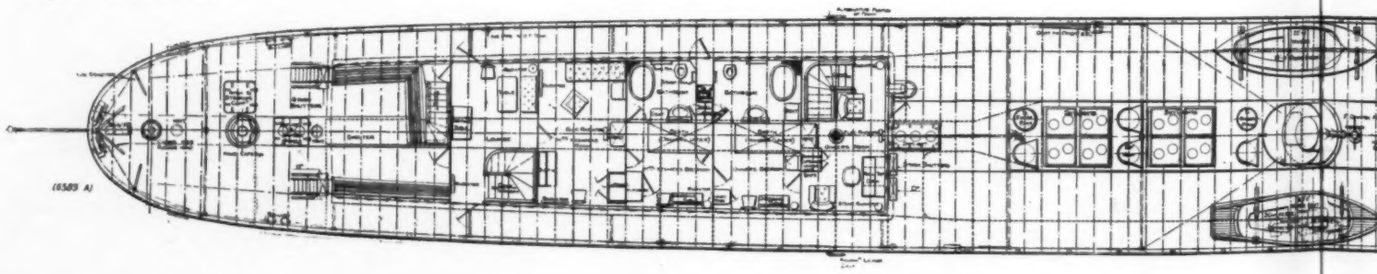


Fig. 4. LOWER DECK

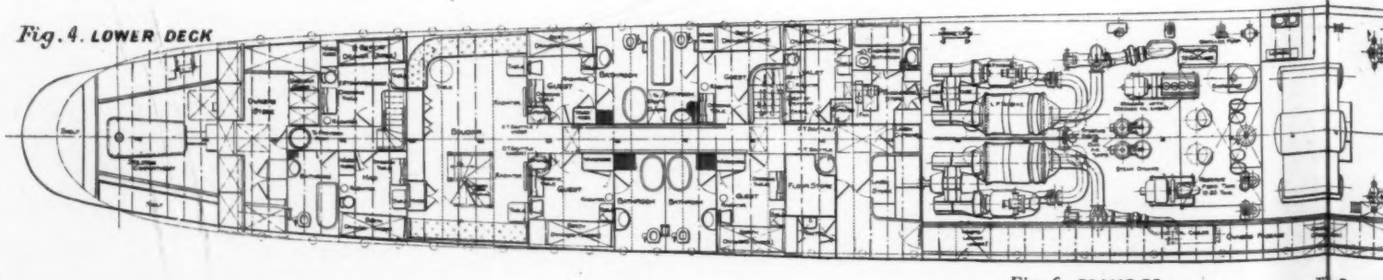


Fig. 5. HOLDS.

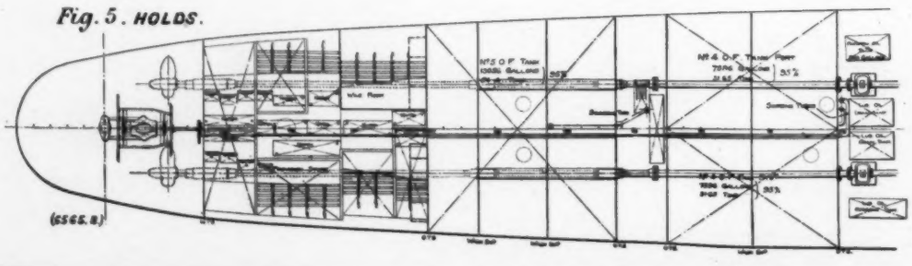


Fig. 6. FRAME 70. LOOKING FORWARD.

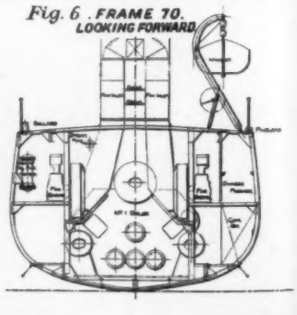
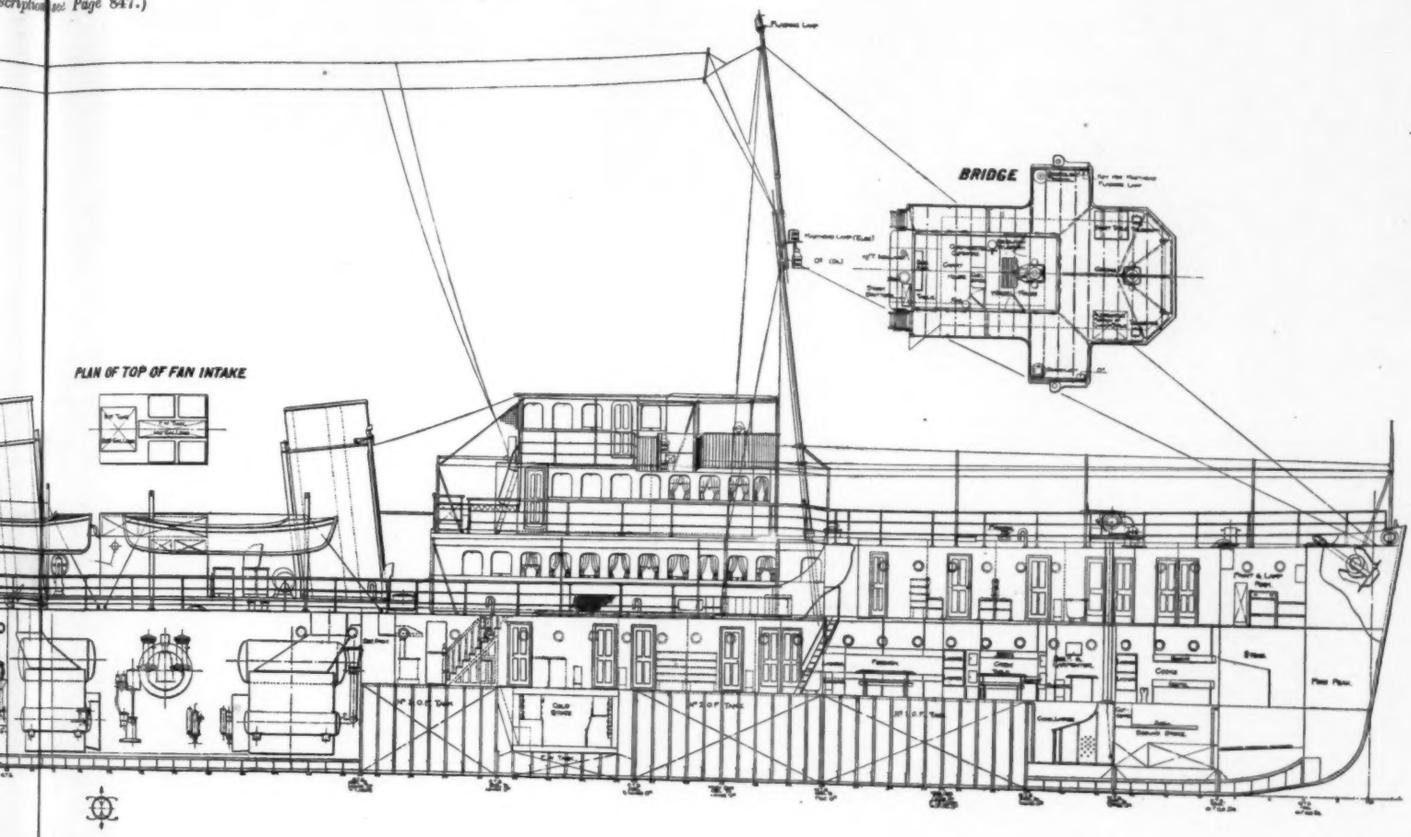


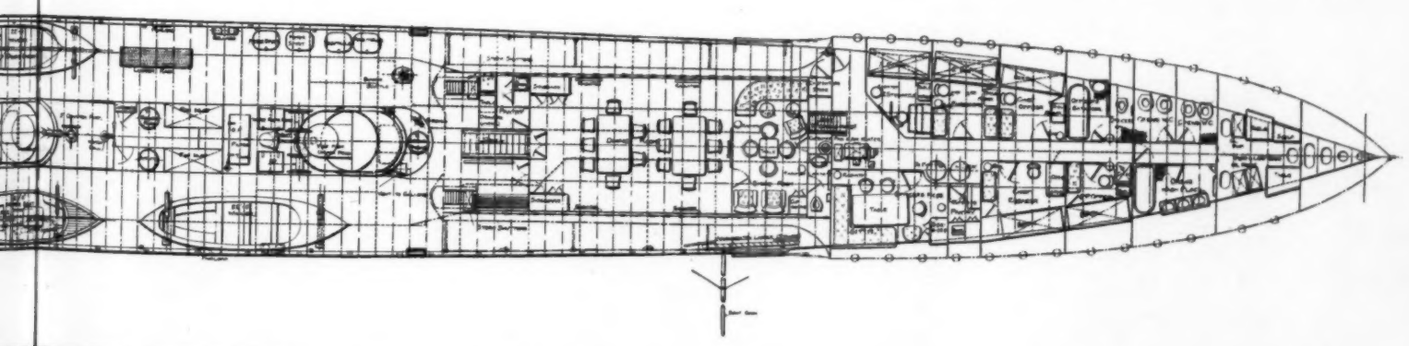
Fig. 7. FRA

DRIVEN YACHT "CUTTY SARK."

LIMITED ENGINEERS AND SHIPBUILDERS, SCOTSTOUN, GLASGOW

(scription see Page 847.)





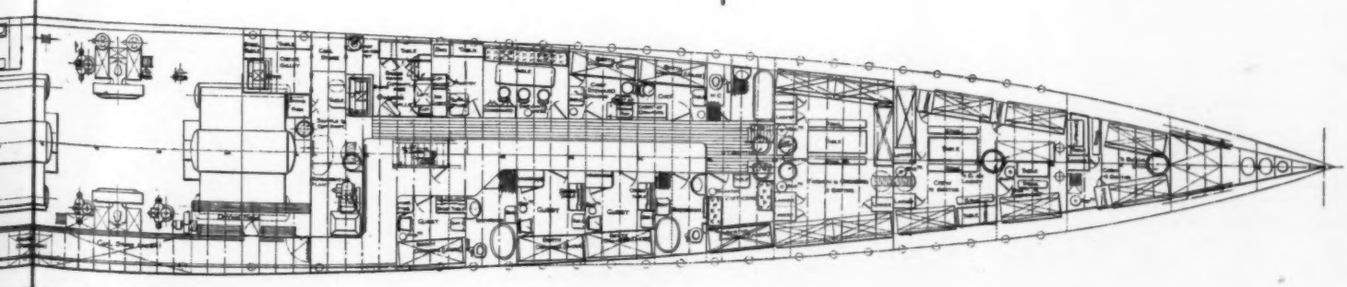
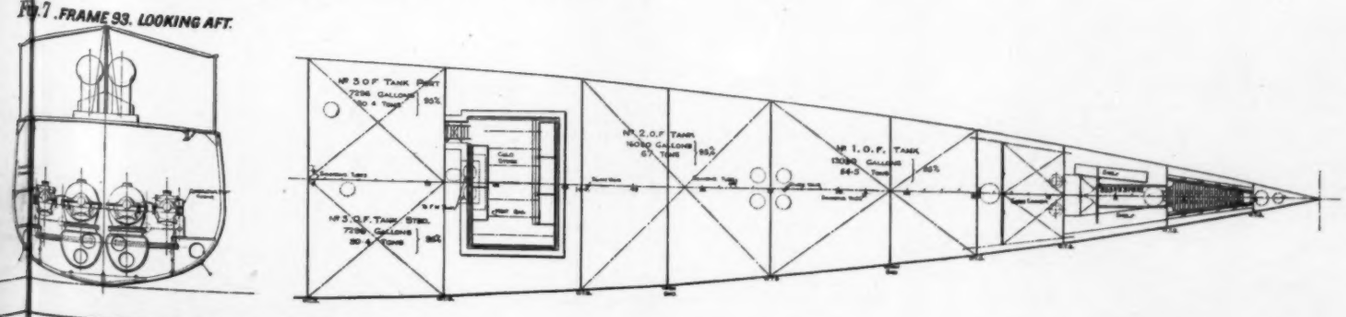


Fig.7. FRAME 93. LOOKING AFT.



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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

SUBSCRIPTIONS, HOME AND FOREIGN.

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Thin paper copies	£2	18	6
Thick ,, ,,	£3	3	0
For all other places abroad—			
Thin paper copies	£3	3	0
Thick ,, ,,	£3	7	6

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All accounts are payable to "ENGINEERING," LIMITED. Cheques should be crossed "The National Provincial and Union Bank of England, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford Street, Strand, W.C.2.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.

TELEPHONE NUMBERS—3063 and 8568 GERRARD.

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With a Two-Page Plate of the TWIN-SCREW TURBINE-DRIVEN YACHT "CUTTY SARK."

NOTICE.

A few months ago the Proprietors of "ENGINEERING" were compelled to advance the price of this Journal to 1s. per copy, owing to the enormous increases in the cost of paper, engravings and printing, &c. Now higher transport and delivery charges involve a further increase to 1s 2d. per copy, and this price dated from and included the issue of Friday, April 2, 1920. As the postal rates have been again increased, the price of single copies sent by inland post is now 1s. 2½d.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers; therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 837.

ENGINEERING.

FRIDAY, DECEMBER 24, 1920.

TEAM WORK.

TO-NIGHT, according to tradition, Santa Claus will visit us again, and as the famous old gentleman always somehow manages to keep up with the times, the youngsters will be sure to find to-morrow their stockings, if they are big enough, filled with Meccano sets and other toys reflecting the engineering spirit of the age. We have recently been informed, in confidence, that our friend has given up his reindeer sleigh, and taken to an airship which he finds can hover infinitely better than his former vehicle, and is, therefore, much more convenient for the purpose of his annual journey. This is but one of countless ways in which the engineer has influenced the present-day mode of keeping Christmastide. Let us consider a few others.

That Yule logs are grown scarce, we are all well aware, but we replace them by coal cut in the pit and raised to the surface by our machinery, and brought to our homes by motor lorry. This, some may think less romantic than the former usage, but it is still full of assurance of the genial warmth and kindly blaze which does so much in this dismal climate to keep us cheerful in our homes when the air is raw and forbidding without. It is the time for social intercourse and friendly greeting. We have only to think of absent ones to send them, now-a-days, seasonable salutations across the globe by wireless. The Englishman keeping the feast with a smoking plum pudding, under a torrid Indian sun, knows, by his mail, that he is less than three weeks from Home. Closer at hand we have immensely multiplied the number of family reunions. We wake on Christmas morning to the merry peals which we owe to a craft which acted, so to speak, as nurse to our profession in its younger days, and now serves us as an indispensable and honoured handmaid; and the endless chorus of joy and praise which circles the earth this happy day is gloriously augmented by grand-organ music, for which, if not the *motif*, we supply the power in either electric or hydraulic form.

Darkness will vanish at our touch, and "the lorde of misrule or master of merrie disportes," though grown somewhat more sober than of yore, can with our help lengthen the hours of enjoyment at his pleasure. Without our co-operation the theatres and pantomimes would prove unspeakably depressing; we pile the festive board with meats, rare fruits, spices and flowers, which we alone can safely carry from the distant countries of their origin. We bring to the markets holly and mistletoe, to the delight of young hearts, for whom also we usually make entertainment with Christmas science at our learned institutions. Can any Scrooge continue in his gloom and solitude in such a world? The Cricket chirps, and the Kettle hums, and—

> "Now all our neighbours' chimneys smoke,
> And Christmas blocks are burning,
> Their ovens they with bak't meats choke,
> And all their spits are turning."

Our heart warms to our fellows, and just for this time we will overlook the smoking chimneys if they betoken cheerful hearths below; we will temporarily dispense, too, with the company of our confrères of the gas stove and electric heater—excellent good fellows in their ways, but, it must be owned, a trifle dull for this occasion. Now, or never, will the Tankertons and Scrooges thaw in the glow and warmth which is diffused abroad, and men come to feel, in the words of the Nephew, that they are fellow passengers through the world, instead of creatures of another race bound on another journey. It is the season of goodwill, when selfish thoughts dissolve in wider circles, and surely, with this feeling in the air, the time is not unfitting for considering whether more of this same virtue cannot be translated into our work-a-day life, to help us to a future more glorious than our resplendent past.

It was cheery goodwill, and a spirit of comradeship among all engaged in the Great Adventure which won the war for us. The men who willingly lost themselves in the whole, and became "details" in the game saved to us our heritage. It was the team work of the Forces, with each man out to win the match for the credit of his side, his individuality sunk in the all-sufficing hope of victory, that brought us success—in contrast with which the attitude of the piece workers at home seemed like that of the pot-hunting athlete individually struggling after prizes. Need we ask which of the twain gave the greater service, and made the sacrifice?

Team work developed to its highest pitch in the Navy, yet carries right through the Army just as well. The *esprit de corps* of the unit is one interpretation of it—the collective effort to make the present worthy of great traditions. It was team work which enabled troops from all parts of the Empire to fight side by side, and which finally resulted in the overwhelming issue for the Allies on the large scale, just as it contributed to the brilliancy of such small affairs as our trench raids. And it was the same idea that brought our women into the struggle.

His Royal Highness the Prince of Wales has recently reminded us that this thing—so necessary in the hour of danger, is equally indispensable now, that we must all pull together with a true spirit of comradeship and co-operation in all our affairs. Can any engineer doubt it? Listen!

> They're all awa'! True beat, full power, the clanging chorus goes
> Clear to the tunnel where they sit, my purrin' dynamoes.
> Interdependence absolute, foreseen, ordained, decreed,
> To work, Ye'll note, at any tilt, an' every rate o' speed.
> * * * * *
> Now, a'together, hear them lift their lesson—their's an' mine:
> 'Law, Orrder, Duty an' Restraint, Obedience, Discipline!'
> * * Eh, Lord! They're grand—they're grand!

That is M'Andrew's Hymn—the nineteenth century engineer's rendering of Paul's lecture on the human body, addressed to the people of Corinth. It needs no interpreting to us, and, mark ye, behind it all is the bit of a controlling hand, to see the cylinders supplied with steam, the bearings oiled, and the boilers fed with coal and water as they should be.

In the best of all games we have "outsides" and "the pack." None of the latter stints his effort because his play brings less individual kudos than does that of the former. Also be it noted we have a captain, perchance a manager, and others in the organisation of the team. Can it be that this spirit of corporate being of so great value both in sport and war, is really of no import in industrial life? Yet in most cases we have the management alone striving for the prosperity of a firm, and employees only interested in themselves, and at the most, in what they can make on piece-work. We are told of the awakening of labour, and of a desire on the part of the men to feel that they are living a wider life than they were used to before the war. It may be taken as a fact that they are not solely concerned about wages, though the frequency of their demands might cause that to be thought. But had that been the case, would they have volunteered so promptly when the call came? And now that they have returned to civil life probably they have brought back with them a bit of the same

feeling of "wanting to be in it." Demobilisation has meant a very sudden reversion from team work to individual effort, with little beyond the pay envelope to satisfy both body and mind. Here it may be something is lacking. They tell us labour does not want to manage; it is not an essential feature of corporate effort that it should. The "pack" certainly does not on the football field, nor does the engine control its own operation. If the team idea could be instilled into the mind of our men we certainly think it might do something to satisfy the present nebulous aspirations which even labour itself seems to find it so difficult to state clearly.

In the coal-mining industry it is already on trial, and though, of course, it is too early to speak definitely of its working, a decided improvement has resulted in output and wages. In this industry it has been arranged on so wide a footing that there are no opposing teams to play—only "bogey" in the form of a base line. Another less comprehensive effort in the same direction has been recently mentioned in our columns—not universally applicable, but already of proved value in certain branches of the industry. In this, zest is added to the game by the retention of keen competition between firms. The base line "bogey" is still there, but over and above that there is the contest between live organisations. In both these experiments the endeavour has been made to enlist the interest and goodwill of the men in combined effort in a scheme offering mutual advantage to all concerned, and that without interfering with skilled and well-tested management. It is, we hold, insufficient to make, for instance, machine men alone anxious for high output, while leaving others supremely indifferent. The indirect ways of affecting machine or departmental output are too numerous for it not to be necessary to rope into the game every single person about a works, and we feel sure that if this could be accomplished, benefits could be won for the nation not less than those which good leadership, staffwork and sound team work have gained for us both on the playing- and the battle-field. Industrial peace must surely follow hard on the development of goodwill and such co-operation. A summary of the disputes of the last two years shows that 61 million working days have been lost during that period, or roughly 100,000 persons on strike every single day of that time. Something, it will be admitted, is sadly needed—and needed promptly—to put an end to such a state, and get labour to throw itself seriously into the struggle which confronts us.

POSSIBLE DEVELOPMENTS IN AERO ENGINES.

In the early days of aviation the main desideratum in connection with the design and construction of the engine was to produce a motor capable of developing the requisite power for the least possible weight. The question of fuel consumption, at that time, was of secondary importance, since for the short flights then possible, the weight of fuel to be carried for an uneconomical engine would be but little greater than that required for an engine of the highest possible efficiency. The matter, however, became of greater importance as the powers of aero engines were increased and flights of longer duration were undertaken. In a flight of several hours an aero engine may consume many times its own weight of fuel, so that it may well pay to install an engine with a greater weight per horse-power if it have a higher efficiency and can consequently effect a saving in the quantity of fuel which must be carried. The cost of the fuel itself is now sufficiently high to encourage economy in its use, but when it is remembered that, in a commercial machine, additional paying load equal in weight to the petrol saved can be carried, it is not difficult to realise that the efficiency of the engine may prove the determining factor in the success or failure of an aeroplane service. In a commercial airship service the effects of this feature would be felt with much greater force, since with lighter-than-air craft the engines would be required to run for very long periods without replenishing the fuel supply.

Fortunately, or perhaps unfortunately from some points of view, the petrol engine is a fairly efficient means of converting the heat energy in the fuel into mechanical energy at the propeller. The best modern aero engines, in fact, have a thermal efficiency only 4 per cent. or 5 per cent. lower than the highest attainable from the cycle on which they operate, so that it is obviously only possible to effect any material increase in efficiency by modifying the cycle, the composition of the fuel, or both. Some of the means available for improving efficiency have, however, been investigated by Mr. H. R. Ricardo, using the experimental engine with variable compression gear, illustrated and described on page 325 *ante*, and these were explained and the results obtainable indicated in a valuable paper read by him before the Royal Aeronautical Society, on Thursday of last week. This paper we hope to reprint at a later date, but the results are of quite sufficient general interest and importance to justify a brief reference to them now.

The theoretical efficiency of the cycle on which practically all modern aero engines operate, is given by the formula $E = 1 - (1/r)^{\gamma - 1}$ in which r is the compression ratio and γ is the ratio of the specific heats at constant pressure and at constant volume. Without considering the properties of the working fluid, it is evident that the efficiency of the cycle may be increased by raising the compression, but with petrol the compression is limited by the tendency of the fuel to detonate as the compression is raised. Mr. Ricardo has found that a light petrol, freed from aromatics, but conforming in every way with the Air Ministry's specification for aircraft spirit, detonates under normal conditions at a compression ratio of 4·85 : 1, but that by adding 20 per cent. of toluene the compression can be raised to 5·57 : 1 before detonation occurs. By this means the efficiency has been found by actual test to be raised from 31·1 per cent. to 33·5 per cent. and the mean-effective pressure from 131·8 lb. per square inch to 140 lb. per square inch. The weight of the fuel per unit of heat contents is only increased by 2 per cent. by the addition of the 20 per cent. of toluene, and as the increase in efficiency is over 7 per cent. the net gain is far from negligible.

Similarly, by adding a certain proportion of inert gases (in the form of cooled exhaust gas) to the cylinder charge, Mr. Ricardo finds the compression ratio, with petrol, may be made as high as 7·5 : 1. It has been found possible by this means to raise the compression to more than 6 : 1 without any reduction in the power output, and, at the same time, to improve the economy of the engine by as much as 6 per cent. This particular improvement, of course, costs nothing and does not increase the weight of the engine. A good idea of the possibilities in this direction may be gained from some interesting figures given in the paper. From these it appears that the limiting thermal efficiency of an engine with a compression ratio of 4·85 : 1 is 32·7 per cent., but the latter figure can be raised to 38·6 per cent. by increasing the compression ratio to 7 : 1 with the aid of cooled exhaust gas. The engine could still be run full out on the ground with perfect safety and with very nearly the same output as that obtained from the lower-compression engine. Moreover, reducing the proportion of exhaust gas as the machine ascended would provide an efficient means of compensating for the increase in altitude.

There are also interesting possibilities of obtaining increased economy, together with a longer life for the engine parts, by controlling the power output by means of the mixture strength, and these have been investigated by the author of the paper. In an internal-combustion engine, as normally operated, it is not possible to reduce the mixture strength indefinitely for running at low powers, since when the mixture has a lower heat energy than about 40 ft.-lb. per cubic inch, serious loss of efficiency occurs owing to incomplete combustion. The desired result can, however, be achieved by means of stratification, *i.e.*, by supplying the cylinder separately with a small charge of combustible mixture and a large charge of air, and keeping the two charges separate until after ignition has taken place. It would certainly seem rather difficult to accomplish this in practice, but we understand that Mr. Ricardo has succeeded in running two engines over the whole range from dead-light load to full load by controlling the fuel alone. From a curve given in the paper it appears that, in an experimental engine with a compression ratio of only 5 : 1, the efficiency rises to a maximum of 37 per cent. at one-third full load, which would be equivalent to a consumption of rather less than 0·36 pint of benzol per indicated horse-power hour. He has also had a 24 brake horse-power gas engine running on this system for some nine months under violently fluctuating loads with perfectly satisfactory results. It must be remembered that, in this method of working, the maximum temperature in the cylinder is practically proportional to the load, and the losses due to dissociation and change in specific heat, as well as the direct loss of heat, all diminish as the load, and therefore the temperature is reduced. It is thus not only possible to obtain higher efficiencies by this means than by any other, but also greatly to reduce the liability of the engine to mechanical failures, since most of these are caused by the high temperatures reached during the cycle. Mr. Ricardo also mentions in this connection that a comparatively small reduction in power output from an engine controlled as above described, will greatly simplify the difficulties of air cooling; he has, in fact, been able to run a water-cooled engine at reduced loads for any length of time with no water in the jackets.

We have not dealt in this article with all the possible methods of improvement considered in the paper, although we have referred to those which seem most promising. Further research is admittedly necessary in connection with some of them, but there appears to be no great difficulty in applying any, or all, of the suggested improvements to a single engine, and it would be extremely interesting to see how nearly the results obtained under ordinary working conditions agreed with those to be anticipated from the experimental work. In conclusion, we should mention that most of the investigations from which the data given in the paper have been obtained were made on behalf of the Asiatic Petroleum Company, Limited, and the thanks of all interested in the development of aero engines, and other internal-combustion engines, are certainly due to that firm for thus permitting their free publication.

LIQUID OXYGEN EXPLOSIVES.

On several previous occasions we have referred in these columns to the use of liquid oxygen as an explosive agent. First used to any extent, we understand, on the Simplon Tunnel, liquid oxygen explosives made a great deal of headway on the Continent during the war as the scarcity of ordinary blasting agents became more and more acute. The new method was gradually reduced to a fairly practical state, and although hostilities are at an end, continues, we believe, to be used to a considerable extent. The United States Bureau of Mines, having first begun to investigate the possibilities of this type of explosive in 1917, is still continuing experimental researches on the subject, though it has already arrived at a number of conclusions which tend to confirm previous information from Continental sources.

For explosive purposes liquid oxygen is used in the presence of carbonaceous matter of some kind. At present there seems still to be some indecision as to what this should be. Soot, wheat dust, straw powder, sawdust, powdered cork, petroleum and other substances have been tried. The Simplon compound consisted of 20 per cent. crude petroleum, 30 per cent. soot, and 50 per cent. kieselguhr, and this material impregnated with liquid oxygen gave better results in the Bichel gauge test than gelatin dynamite, blasting powders, &c. The kieselguhr, it must be noted, is added to increase the power of absorption of the cartridge. It does not otherwise affect the explosive, the power of which is dependent upon the combination of the oxygen and carbon in the mixture. The United States Bureau experiments, so far published, have been concerned with samples made up of kieselguhr, crude oil and oxygen; kieselguhr, crude oil, lamp black and oxygen; and another composition in which a rather large proportion of wood pulp was introduced in place of the lamp black. All three compounds were found to be more powerful

by from 4 per cent. to 12 per cent. than 40 per cent. straight nitro-glycerin dynamite, when subjected to the standard ballistic pendulum test of the Bureau. There seems to be little doubt, therefore, that as regards power such explosives are fully up to requirements.

The advantages claimed for these explosives are considerable, though they are off-set by some disadvantages which are too prominent to be overlooked. The cost per unit of material blasted is said to be quite reasonable, and the system introduced by force of circumstances during the war is still being adhered to on the Continent for economic reasons. Where the liquid oxygen is manufactured at the mines by efficient plant producing oxygen of from 85 per cent. to 95 per cent. or even higher purity, the cost at the working face is said to be comparatively speaking low. Then, again, as the materials only become explosive when the carbon is soaked in the oxygen, which is done only at the working face, at the last minute, all risk in transportation and storage is obviated. There is practically no risk of premature ignition, while the dangers of misfires disappear, both at the face, and by the subsequent explosion of cartridges in the mined mineral, since after a lapse of half-an-hour or so the oxygen has evaporated and the cartridge has become harmless.

The disadvantages are, however, still considerable. Two, at least, must carry considerable weight. The first of these is that on account of the risk of igniting fire-damp this explosive cannot be used in gaseous, or in dusty mines. The American experiments on this point confirm previous German experience, and no thorough solution has, so far, been forthcoming, though it is understood promising work has been done with the addition of graphite and salt to the carbonaceous constituent with the object of lowering the temperature during ignition, and deadening the flame. Again, if the explosive is not fired quickly after preparation the evaporation of the oxygen may result in the production of a considerable quantity of CO, instead of the whole being reduced to CO_2. This may occur to a disagreeable and even noxious degree. This evaporation also has other indirect results as, for instance, the necessity of firing charges so soon after preparation that only two or three shots can be fired at once. As liquid oxygen has a temperature of about —185 deg. C., it quickly evaporates in contact with the relatively hot rock of the hole, and the gas is sometimes driven off so violently as to blow out the stemming. For this reason a gas escape has to be left when tamping. A good deal of practical work has been brought to bear on this aspect of the subject, and various attempts have been made to render the cartridges less open to this objection by means of insulation.

The problem of dealing with this question of evaporation of the liquid oxygen has been attacked in two ways, both of which have met with some success, which, however, cannot be considered by any means complete as yet. In one system the cartridge is only impregnated with oxygen after being placed in the hole. This system is rather cumbersome in practice, and does not lend itself at all well to large charges, or work with deep holes. In the second system, the cartridges are soaked and then inserted in the hole. The latter system involves the use of open vessels for soaking, whereas in the first the cartridges can be charged *in situ* by means of an almost closed and fully insulated vessel. The soaking method, with preliminary cooling of the cartridge, appears to be most favoured on the whole, and the required apparatus seems to have been brought to a fair degree of perfection.

The liquid oxygen made at the mine is put into containers of a capacity of about 5 litres, which is sufficient for 12 or 13 cartridges about 1¼ in. in diameter by 9 in. in length. This quantity serves for a shift of eight hours for two miners, and one or two loaders. The container consists of a double-skinned brass vacuum flask with a long neck, and charcoal, on the Dewar system, in the exhausted space between the two skins. The vessels are exhausted as far as possible, and when the liquid air is introduced into the flask the charcoal absorbs the residual air, and an almost perfect vacuum results. The space does not need to be exhausted more than once a twelve-month, and evaporation is said to be only 4 per cent. per hour. The container is further enclosed in a strong metal case, packed inside with insulating material. The dipping vessels are usually comparatively tall, and of uniform and moderately small diameter all the way up, open at the top, and likewise usually constructed on the vacuum-flask principle, with a lined protecting casing outside them. They hold four cartridges at a time. The cartridges require to be soaked for about 15 minutes, and must be exploded within 5 to 15 minutes of being removed from the dipping vessel, according to the work. As previously stated, the cartridges are usually pre-cooled by immersion in the cold oxygen gas before being dipped into the liquid itself. The cartridges are exploded either by special fuse, or by electric igniters or detonators. Ordinary fuse cannot be used as it burns rapidly if soaked with oxygen, and the special fuse used is made with braiding which is incombustible. A detonating cap is used with the fuse. The electric detonator contains no detonating material, merely igniting material such as powdered cork, and can, therefore, only be detonated after soaking in oxygen.

WORKMEN'S COMPENSATION.

IMPORTANT judgments were given by the House of Lords last week in three appeals from decisions of the Court of Session in Scotland on stated cases under the Workmen's Compensation Act, 1906—A. G. Moore & Co. *v.* Donnelly; Fife Coal Company, Limited, *v.* Colville; Fife Coal Company, Limited *v.* Gordon. The question in all three cases was the same, viz., whether the contravention of a statutory order under the Coal Mines Act, 1911, by a miner, who, as a result, suffered death or serious and permanent disablement, took him outside the sphere of his employment so that compensation was not payable. The development of the law on the subject is interesting. Under the original Workmen's Compensation Act of 1897 a claim for compensation in respect of an accident due to a deliberate breach of a statutory order could in most cases have been successfully resisted on the ground that the accident was due to the workman's serious and wilful misconduct. Since the Act of 1906 was passed that defence has no longer been available in cases where death or serious and permanent disablement resulted from the accident. Accordingly the Scottish case of Conway *v.* The Pumpherston Oil Company, Limited, in 1911—in which a miner had lost his life through going to look for a pick, with a naked light, in an "upset" in which there was dangerous gas, despite the fact that it had been boarded across and marked "No road up here" by a fireman—the employers rested the defence not on a plea of serious and wilful misconduct but on the plea that in going into the upset despite the fireman's prohibition the miner had gone outside of the scope of his employment and that the accident had, therefore, not arisen out of and in the course of his employment. The Court of Session, however, held that the man was within the "sphere" of his employment notwithstanding his disobedience of the fireman's prohibition, and that compensation was payable. That decision was followed by the Court of Appeal in England in a similar case in 1911—Harding *v.* Brynduu Colliery Company, Limited—but these decisions have now been overruled by the judgments referred to. As the three cases are somewhat similar, one of them—Fife Coal Company, Limited, *v.* Colville—may be taken as typical.

The Lord Chancellor's statement of the facts was to the effect that a stone miner, John Colville, was employed by the appellants, the Fife Coal Company, Limited, in September, 1919, in one of their pits. He and a man called Canavan were driving a road through sandstone in the pit and bored two shot holes in the sandstone and took the ordinary steps to fire the shots. They then retired, and Canavan's shot duly went off. Colville thought that he had failed to light his "strum," and after waiting ten minutes the men returned to the sandstone face. While they were looking for Colville's "strum" his shot exploded and he was killed. In accordance with the Explosives and Coal Mines Order of September 1, 1913, the men should have waited at least an hour before approaching the shot hole, and a notice calling the workers' attention to this Order had been conspicuously posted at the pit head by the company. The Arbitrator found that the company were liable to pay compensation to Colville's dependants and on appeal the Court of Session agreed with the Arbitrator. The Lord Chancellor, however, said that where a prohibition for which the employer was responsible, in matters comparable to those under discussion, was brought clearly to the notice of the workman his breach of it took him outside the sphere of his employment, so that the risk in which he involved himself ceased to be reasonably incidental to his employment. He accordingly held that compensation was not payable. The other noble and learned Lords gave judgment to the same effect.

The Lord Chancellor added that he did not lay particular stress on the fact that the rule violated by the workers was of statutory origin, because on principle no distinction could logically be drawn between a prohibition founded upon statute and one imposed by the employer to regulate the employment. It will be observed that the same result has been attained as if the plea of serious and wilful misconduct had been still open to the employers in cases such as these.

NOTES.

THE ELECTRIC DEVELOPMENT ASSOCIATION.

THE convenience of electrical apparatus and appliances is so well known to engineers that they are, perhaps, apt to assume that the information is common property. This is, however, far from being the case, and in the domestic sphere, for instance, the comparatively small use of electric irons, or electric toasters on the breakfast-table, must be attributed to a considerable extent, to a lack of appreciation of the fact that these appliances exist. No doubt most people have had these things brought to their attention at one time or another, but continued and reiterated insistence is necessary before the average man effectively realises facts which do not immediately concern him. This is the understanding on which advertising and publicity work must be based. The gas interests have for a long time now carried on a very able propaganda directed both at the domestic consumer and the manufacturer, and it is the business of the British Electrical Development Association to carry out the same kind of thing in their own sphere. The purpose is not to advertise the products of any particular manufacturer or manufacturers, but to do everything possible to point out to the general public, and if necessary, to specially selected publics, the advantages and conveniences of electrical working generally. The Association gave a lunch at the Hotel Cecil on the 17th inst., at which Mr. Hirst, the President, and others spoke, and at which the aims of the body were explained. The sphere which it has to work is a very promising one, and the Association should ultimately be able to do much good for its three types of members—electricity suppliers, manufacturers and wiring contractors.

INDUSTRIAL PROSPECTS.

A somewhat black picture of the present and immediate future of the engineering industry was painted by Lord Weir in his presidential address to the Junior Institution of Engineers on the 17th inst. In the absence of such statistics as would be furnished by a census of production, Lord Weir based his examination of our engineering trade on export figures, and by means of a series of simple diagrams was able to show very clearly how far we yet are from attaining the position we held in pre-war days. As Lord Weir pointed out, if we are to maintain the higher standard of living which grew up gradually during the war, it is essential that our level of production should not only equal but should greatly exceed that of 1914. He referred to the fact, which has been pointed out by Mr. Clynes, that the relaxed production per worker which has been one of the most important industrial factors in the period since the armistice, has resulted not in leaving more work for other people, but in leaving less work

for anybody. He also referred to the absurd position in which we now find ourselves with tens of thousands of men out of work and certain industries—notably building—held up by shortage of labour. The same thing applied to the moulding trade. This question of building trade shortage apparently is at last to be tackled, but in what appears a very undesirable way. The proposal that the State should subsidise building trade unions to persuade them to do their common duty and to act in the interests both of the public and themselves, is indefensible. At the end of his address, Lord Weir put forward some of his remedial proposals, including the stabilisation of wages for twelve months, and other matters which we dealt with in some detail in our issue of October 29 last.

Trade Union Activities.

The judgment of Mr. Justice Darling, given last week in the trade union case of Miller *v.* Hurry and another, is an example of the well-known principle that one who induces another to do an illegal act against a third person is liable for the loss and damage caused thereby to that third person. It appears from the judgment that the plaintiff, after being demobilised, endeavoured to resume his previous occupation by setting up in business on his own account as an undertaker. He accepted an order to carry out a funeral, and as he had no horses of his own he contracted with a Mr. Merrett, a funeral carriage proprietor, for the supply of a coach and a pair of horses for the funeral. The plaintiff had been endeavouring to become a member of the British Undertakers' Association, to which Mr. Merrett belonged, but his application for admission was refused. The defendant, Hurry, was the secretary of the association, and Mr. Justice Darling found that when Hurry heard of the plaintiff's contract with Merrett, he telephoned Merrett and forbade him to supply the plaintiff with the carriage and horses for the funeral, and added that he, Hurry, was stopping the plaintiff's supplies all round. He also threatened that Merrett would be fined and boycotted if he supplied the plaintiff. As a result of this, Merrett broke the contract and refused to supply the carriage and horses. Mr. Justice Darling accordingly held that Hurry had procured and induced Merrett to break the contract. He held also that the defendants had conspired together to prevent the plaintiff from being elected a member of the Association, although the rules of the association were so drastic that it would be almost impossible for anyone who was not a member to carry on business as an undertaker unless he were in such a large way of business that he could do every branch of the business himself. His Lordship said it was shocking that the plaintiff, who had done his duty during the war, should be prevented in this manner from getting a living when he came back from it, and that if the defendants succeeded in their efforts, the plaintiff would become one of the unemployed. He gave judgment against the defendants for conspiracy and against Hurry for unlawful acts and assessed the damages at 150*l.* in favour of the plaintiff. The case is an interesting contrast to the "stop lists" case decided by the Court of Appeal a few days later, to which we hope to refer further next week.

Relief from an Electric Lighting Contract.

A case of considerable importance, to electric-supply companies was decided last week by Mr. Justice P. O. Lawrence. We refer to North Metropolitan Electric Power Supply Company *v.* Mayor of Stoke Newington, where the plaintiff company secured the annulment of a contract to supply electricity in bulk on the ground that, owing to the alteration of trade conditions occasioned by the war it could not be enforced without serious hardship. It was in 1917 that the legislature first invested the Courts with power to grant relief from burdensome contracts; but so far as is known, this is the first case in which the jurisdiction has been exercised in favour of a company supplying electricity. The explanation may be that, knowing the Courts have power to grant relief, parties to contracts of all kinds have been ready and willing to modify terms which are too onerous. In the present case the facts were that the company had agreed to supply electricity in bulk under various agreements of which the most recent was dated October 24, 1911. They alleged that owing to the rise in cost of coal and labour it was impossible to supply in accordance with the agreements except at heavy loss. Indeed, it was shown to the satisfaction of the Judge that the annual loss to the company under the agreements was no less than 2,622*l.*, and this although the actual amount of energy supplied at the date when the action was brought was double the amount supplied at the beginning of the war. "In my opinion," said his Lordship, "the meagre dividend paid by the company in 1919 on its ordinary share capital, and the fact that nothing was set aside in that year for general reserve is a sufficient answer to the suggestion that the company can well afford the permanent loss which, in my opinion, would result if the Court were to refuse relief." It is interesting to notice that this decision was only arrived at after the learned Judge had "considered the offers which have been made," and that, although he had power to do so, he did not vary or modify the contract, but simply annulled it. His judgment throws no light upon what the position will now be. It would seem that the company are now in a position to say: "We shall not supply any more electricity in bulk except on our own terms." It should be emphasised that Mr. Justice Lawrence made it plain that the very arbitrary jurisdiction which he was called upon to exercise is one which the Court will only act upon after a consideration of all the circumstances; but the fact that it will so act in a proper case may strengthen the hands who desire to obtain relief from burdensome contracts by friendly negotiation out of Court. As an example of a case in which relief was refused, reference may be made to Waubrs *v.* Association Internationale (1918) W.N. 267. There a contract had been entered into by the defendants to supply the plaintiff with soap. The defendants protected themselves by a sub-contract. Administration restrictions created difficulty in supplies, as a result of which the sub-contractor failed to carry out his contract as did also the defendants. It was held that the defendants were not entitled to relief, as they could purchase soap in the open market. This was not a case of serious hardship within the section.

LITERATURE.

Margarine. By William Clayton, MSc.(Liverpool). Illustrated. London: Longmans, Green and Co. 1920. [Price 14*s.* net.]

This is one of a series of monographs on industrial chemistry, edited by Sir Edward Thorpe, and designed to demonstrate the close and fundamental connection existing between principle and practice, by furnishing examples of the application of recently acquired knowledge to modern manufacturing procedure. In the years before the war, chemists developed a tendency to limit attention to the philosophical side of the science and to neglect the improvement of manipulative skill and technology. The present series is calculated to restore the balance, by displaying the valuable assistance that original research has rendered in the opening out of new avenues for the wider prosecution of trade and commerce. If the trade of margarine manufacture came into existence under the taint of illegitimacy, if its object originally was the adulteration of butter, it has purged itself of its unlawful character, and owes its rapid increase and prosperous position to-day to the process of oil hydrogenation, the result of pure chemical research. The extent to which the public has benefited by this discovery can scarcely be appreciated, for Mr. Clayton states that this monograph giving so much information concerning the growing industry, is the first of its kind to appear in any language. One can understand that in the early days there were very good reasons why the public was not invited to consider the methods too narrowly, but since margarine manufacture has become a legitimate industry it has nothing to gain from secrecy, but may court inquiry into its merits as a progressive and prosperous business. Indeed, it is hard to believe that curiosity could so long go unsatisfied, or that those engaged in producing a valuable commodity would make no attempt to instruct the public that they were endeavouring to serve, or to fight down a mass of ignorant prejudice that hampered progress and restricted distribution. The author has not given any statistics to show the output of margarine, but it must be enormous, and this trade has grown in spite of its disreputable origin, misrepresentation and hostility. This commodity may be condemned but it has to be tolerated, it is despised, but it is indispensable. If more were known of its ingredients and the rigour of the tests applied to ensure purity, of its method of manufacture and technical skill involved, of the necessity for care and cleanliness in all processes, not only would much of its unpopularity disappear, but its usage would be greatly extended.

The origin of margarine, Mr. Clayton reminds us, goes back to the time of the Franco-German war, but we imagine there are few who remember the somewhat doubtful success that attended the efforts of M. Mége-Mouries to produce from beef suet a food, that should possess the characteristics of butter and might be used independently, or as an adulterant. We say "doubtful success" for though he undoubtedly led the way in the manufacture of "butterine," a product better in many respects than an inferior butter, it is impossible to approve of the use made of his patent, which in working led to the practice of substituting the manufactured product for butter without the knowledge and consent of the purchaser. The evil repute attaching to unworthy imitation has clung lastingly and mischievously to a promising and economical process. The patent was worked in America without shame or disguise. The slaughter houses of Chicago provided abundant raw material, and a very brisk traffic in butter substitutes arose between Holland and the United States. The wily Dutchman introduced the oleo-margarine into his exported butter with an unsparing hand, and statisticians were not slow to point out that the import of Dutch butter into this country varied in the same ratio as the import of oleo-margarine from the States into Holland. The farmer had no chance with his dairy produce, and there began against the ill-starred margarine a chorus of abuse which has continued uninterruptedly ever since. The manufacture has improved and changed its character: restrictions have been imposed in the interests of agriculture; the new field of bio- and nutritional chemistry has been invoked to declare the true food value of margarine; but the shadow of the evil reputation created in its early days has followed its onward path and diminished the lustre attaching to a successful career.

The main features that have contributed to the advance in the manufacture of margarine are summarised by the author under four heads: I. The use of commercial cultures of lactic acid organisms, usually *B. lactis acidi*, Leichmann, for souring the milk used in churning, in order to impart a butter flavour to the finished product. II. The introduction of vegetable oils and fats, leading to the so-called "nuts and milk margarines." III. The utilisation of hydrogenated oils thus providing a new and extensive source of raw fatty material, and IV., the use of artificial milk, made from vegetable oils and nuts. This milk can be pasteurised, soured and emulsified, yielding a product quite equal to that made with the usual separated cow's milk. Some of these operations, particularly the last, are not discussed so fully as their importance merits. Probably trade interests and special methods adopted in particular factories rendered a more thorough description undesirable, or these may be connected with the technical minutiæ of manufacture the discussion of which is excluded by the general plan of the series.

Broadly viewed the process of margarine manufacture is simple, and the machinery employed is not complicated. The first operation consists in the melting of the fatty ingredients, and whether animal fats are employed as in oleo-margarine, or oils as in vegetable kinds, the mixture is arranged to possess a melting-point at about 25 deg. C. The melting pans are double jacketted so as to permit steam heating, or if required, of water cooling, and are fitted with agitating apparatus. If necessary an artificial colouring is added to the molten materials. This usually takes the form

of an oil soluble dye, a coal tar derivative is generally preferred, displacing anatto, which is open to objection by reason of its method of preparation. Two milligrammes of dyestuff per pound of margarine is approximately the usual allowance. At this stage, in Continental practice, 10 per cent. of sesamé oil is compulsorily added, in order that chemical analysis may detect the character of the product, so jealously do the authorities watch the manufacture.

The preparation of the milk used to flavour the margarine and also to act as an emulsifying agent, offers considerable scope for technical treatment. Some form of pasteurisation process is necessary in order to destroy the pathogenic bacteria and other micro organisms that would impart a disagreeable flavour to the product. Complete sterilisation of the milk is not possible, as the high temperature necessary would caramelise the milk sugar, and give rise to a burnt taste. Hence the heating of the milk is not carried beyond 65 deg. C., and it is then rapidly cooled, but the processes in detail differ in various factories, some preferring comparatively low temperature with long continuance, and others higher temperature for a shorter time. As a result about 95 per cent. of the total organisms are destroyed, and it is important to note that though the germicidal temperature of the dreaded tubercle bacillus is not definitely known, the authorities generally agree that this organism does not exist in milk that has been submitted to a temperature of 65 deg. C. for 30 minutes. When pasteurised milk is used in margarine manufacture it further undergoes inoculation with lactic acid bacteria, and the rapid curdling acidification, which follows, promotes conditions which are unfavourable for the development of any micro-organism that might escape the pasteurising process. In defence of a much maligned trade, it is important to bear in mind that the interest of the manufacturer demands the maintenance of scrupulous cleanliness and hygienic purity of the raw milk used, for the flavour of the finished product is entirely dependent on the milk treatment before emulsification.

The object of emulsification is to imitate the emulsion found in cream and milk, where the fat globules have diameters ranging from 0.01 mm. to 0.0016 mm. A fine and stable emulsion is absolutely essential in order to make a margarine of butter-like texture and consistency, and much skill and ingenuity have been exercised on the process. The production of a margarine emulsion presents many problems of interest to the colloid chemist and some of these the author discusses very instructively, but here we are considering only the mechanical operations. In practice, some form of "margarine churn" fitted with rapidly-revolving baffle plates or similar contrivances is employed, and the liquid constituents are slowly run in, constant agitation being maintained. About 30 gallons of milk and a similar quantity of water are used to a ton of melted oils and fats, but these quantities will vary according to the subsequent treatment of the emulsion, and the possible use of emulsifying agents as glycerine, gelatine, starch, &c. When emulsification is complete, the temperature is reduced to about 30 deg. C., and the custard-like emulsion is run off for cooling. The advantage of rapid cooling is to ensure the maintenance in the solid state of the intimate and finely-divided mixture. The more perfect the emulsion and the more rapid the cooling, the greater will be the resemblance in texture between the margarine and butter. Continuously fed churns have displaced the original churn, and various forms of friction disc arranged to permit the fatty ingredients to be forced through small apertures, with other similar appliances have been employed, but the principle of the churn to ensure complete emulsification remains unaltered.

Rapid cooling was originally effected by bringing the emulsion into contact with ice cold water, whence solid crystals of margarine could be skimmed off. An improvement was effected by discharging the emulsion on to a slanting chute, met by a sheet of icy water and this led naturally to the use of the ice water spray. Each ton of margarine made on the spray system required from 2,000 gallons to 2,500 gallons of water at 33 deg. to 35 deg. F., and in consequence of this drawback, accompanied as it was by an increase in the moisture content of the margarine, other cooling devices have been employed. The form invented by Schou is favoured by the author, and may be regarded as a master patent for many successors. In this apparatus, cylinders rotate in opposite directions and at adjustable distances from each other, the arrangement being such that the thickness of the spread and layer or film of emulsion distributed over the surfaces of the cylinders is determined by the smallest distance of the cylinders from each other. A cooling liquid circulates through the drums on to which the emulsion is fed automatically, so that a thin uniform layer is formed on the surface of the cylinders, which instantly solidifies and is stripped off, as flakes, by means of adjustable knives.

Many variations of the general principle have been recommended and are in practice, but in all, the cooled emulsion requires further treatment to consolidate the mass into the form and appearance of butter. Rolling and kneading the mass in revolving drums calls for little remark, and experience has suggested various methods to compel cohesion of the particles. Salt, preservatives, and flavours, or blended additions as they are euphemistically termed, may be introduced at this stage, but of preservatives it may be said that common salt holds its own and is decidedly to be preferred to the much vaunted boron compounds. Three per cent. of salt in a margarine sample, prevented any serious deterioration after three months' storage, though other samples, containing over 1 per cent. of boric acid, benzoic acid, and salicylic acid, respectively, were quite rancid. The author's own experiments confirm this result, and apart from the inefficient operation of boron as a germicide, physiological objections are alleged against its use in food. The attitude of the public towards margarine is so suspicious, that the industry cannot afford to disregard any additional cause of complaint, whether well or ill-founded. With regard to other additions, the public will endorse Mr. Clayton's remark to the effect that "the truly desirable flavour of butter will be best secured by working with sound raw materials, good milk soured with a carefully-chosen culture of lactic acid bacteria, and a strict observance of hygienic conditions throughout."

This remark will be better appreciated after reading the author's account of the treatment of renovated or "process" butter, a product obtained by the clarification and subsequent re-working of butters of poor quality, or which have been deteriorated during transit or storage. By judicious manipulation, the rancidity and mouldiness are removed and all obnoxious odours and flavours are made to disappear, so that the finished product looks, tastes, and smells, like butter, and will deceive even the trained analyst, for chemically, such renovated butters are identical with genuine butter, and of the various tests proposed to detect the inferior article none is infallible and all fail to respond at times. The author enters very fully into the matter of tests, which are applied at various stages of the manufacture, so jealously is the production of margarine and its congeners watched. Much work is provided for the analyst, but we imagine that experience is often as useful as the most elaborate of chemical or physical tests, that aim at exact quantitative analysis, for it is admitted that margarine can now be made of such a variety of oils and fats, that though in some cases a definite composition can be assigned, yet in many, only a generalised statement of fairly wide percentage limits can be given.

This difficulty in determining the composition of margarine operates to the disadvantage of the trade in inquiries relating to food values. Margarine and butter have practically the same coefficients of digestibility, and it has been shown fairly conclusively that oleo-margarine can replace genuine butter in the diet without detriment. But the estimation of the nutritive value of foodstuffs rests on other data than digestive qualities, or on the relative proportions of protein, fat and carbohydrates which have hitherto sufficed. Researches in bio-chemistry have indicated that there are food constituents too minute in quantity to contribute to the energy supply of the body, but which conceivably act as catalysts in the normal metabolic processes. These indispensable food factors, whether they be known as "vitamines," or by the non-commital term of "fat-soluble A," play no unimportant part in the animal economy, and while abundant in butter fat, are entirely absent in lard, hydrogenated oils, and margarine. From this point of view, such substances form but indifferent substitutes for butter, egg yolk, or even cream and milk.

Margarine prepared from beef fat and oleo-oil may possibly be equivalent to butter, but nut butters and margarines whose base is hydrogenated vegetable oils must be held to be destitute of the "fat-soluble accessory substance." On this ground, it is recommended that children should preferably be fed on butter, but it is confidently asserted that adults possessing stronger digestive apparatus may with absolute impunity replace butter by either oleo or vegetable margarine, provided an adequately varied and balanced dietary is maintained.

The quantity of margarine now consumed is attaining such proportions that its comparative efficiency as a diet cannot be overlooked. Mr. Clayton is more than justified in considering his subject from many points of view, and in each it will be found that he has something novel and weighty to say. He himself has taken a prominent part in many experiments, and investigations designed to illuminate obscure points in the manufacture, and this knowledge at first hand is freely drawn upon in the volume we have reviewed.

Wireless Transmission of Photographs. By MARCUS J. MARTIN. Second edition, revised and enlarged. London: The Wireless Press, Limited. [Price 5s.]

THIS is the second edition of a work, in which the author, a few years ago, described the process for transmitting photographs by wireless telegraphy. We are not able to record the amount of progress made in this development of a method that had been successfully employed when operating with a metallic circuit, because the exigencies of war have interrupted experiments that were hopefully commenced. And yet it may be recalled, that when the plan was introduced some ten years ago, it was urged that the adoption would be of great service to naval and military authorities, as any attempt on the part of an enemy to intercept the messages could be easily frustrated. As far as is known, however, the plan has not served military purposes. Perhaps it was found that if the enemy could not utilise the transmissions he could effectually "jam" them, with even more disastrous results than "atmospherics," which the author assures us can "be easily eradicated by "retouching." From whatever cause, however, we gather that complete success has not been attained, and it may be that this book is put out as an encouragement and reminder, that further efforts should be made to perfect the process. The encouragement would have been greater, if the author had presented a specimen of work accomplished recently, and compared the result with earlier attempts, but unfortunately there is no reproduction of a photograph to serve either as a standard of excellence or to show the quality of achievement.

The author maintains that for long-distance transmission of photographs, a reliable wireless system will prove both cheaper and quicker than transmission over ordinary land lines and cables. This view is formed upon the possible elimination of distortion effects, arising from varying capacity and inductance, where metallic conductors are used. This view is hardly warranted; it may, of course be urged, that photographic transmission would be possible where telephone or telegraphic lines did not exist, but such conditions would also imply that an instructed society was also wanting, and therefore photographs would be of little use. Since, too, distortion has been so effectively overcome by judicious "loading," that it is possible to perceive the minute differences of the human voice and of timbre, little difficulty should be experienced in transmitting the gradations of tone or density, for the telegraphy of pictures differs from the transmission of ordinary messages only in the necessity of ensuring that the signals received

occupy a fixed and definite position on the receiving apparatus.

The history of invention is always interesting and Mr. Martin does well in presenting the steps that have preceded, and possibly directed, the development into its present shape. The forgotten experiments of de Bernochi, though unconnected with wireless transmission, properly so-called, and possessing but a very limited field of operation, were scientifically arranged, and aimed at a method of continuous reproduction that was artistically more perfect than is possible with the mechanical division of a picture into numerous small squares and successively signalling the absorptive power of each of these, by a process more or less discontinuous. Around a glass cylinder carried on a threaded screw shaft, capable of giving vertical motion to the cylinder, a fully developed photographic film was wrapped and a powerful lamp was focussed on a point of the film. As the cylinder was rotated and simultaneously made to travel vertically, the spot of light traced a spiral over the surface of the entire film. The light having passed through the film and been absorbed according to the density, next fell on a selenium cell, whose resistance altered in proportion to the light intensity, and by known means influenced the light of an arc lamp, conveniently placed in the focus of a parabolic reflector from which a parallel beam could be received at the distant station. Here the light of varying intensity passed through a similar apparatus, in inverted order, and finally arrived at a sensitised photographic film, covering a cylinder which must move similarly and synchronously with the sending drum.

The two fundamental devices of producing a light that shall vary in intensity according to the density of the picture, and the exact synchronisation of the sending and receiving apparatus, have remained unaltered, though the methods employed have necessitated alterations in detail. In the Bernochi experiment, the distance of transmission was limited by the necessity of the path of the rays from the parabolic reflector to the receiving mirror being unimpeded, and this defect is removed in the Knudsen process, which utilises wireless mechanism. He adopted the method of breaking the picture up into parallel lines, or bands, by inserting a single line screen between the lens and the plate upon which the photographic picture is recorded. The effect of this screen is to cover the clear parts of the photograph with narrow lines, wide apart, and the dark portion with wide lines close together, wider and closer according to the density of the original. Knudsen used this artifice to obtain an iron-dust picture, in which the quantity of metal varied with the density of the picture. On sprinkling iron dust over the plate before it was quite dry, more dust adhered to the darker and consequently moister portions than to the lighter and drier. A steel needle, attached to a delicate spring, being made to pass over such an uneven surface will be made to vibrate, and by this vibration make and break the battery circuit of a spark coil, which can be made to set up sparking in the spark-gap of a wireless apparatus. In this method the variation in density is made to determine the length of time the current is passing, and much of the success must depend upon the distribution of the iron filings. When a similar spring and needle is placed over a smoked glass at the receiving end, suitable apparatus can be arranged to make the needle vibrate upon the smoked glass plate in unison with the needle at the transmitting station, reproducing the original picture. But to get the crudest result synchronisation in the movements of the plate carrying the iron dust picture and the smoked glass plate must be effected, and ingenious arrangements have been devised which it is not necessary to describe.

To Professor Korn, who obtained very practical results on telegraph wires and demonstrated the possibilities of the selenium cell, we owe further advances. He retained the metal cylinder and stylus, but dispensed with the iron dust, which was a very uncertain factor. He photographed the picture in insulating ink, arranged about the drum in such a way that when the stylus passes over an insulating strip the waves generated are in tune with the receiving station, but when passing over a conducting strip, a portion of the inductance is short-circuited, the period of the oscillation is altered and the two stations are thrown out of tune For receiving, a special type of Einthoven galvanometer was used, the metal string of which is shifted on the passage through it of a weak current, the shift allowing a narrow beam of light to pass to the receiving film which is wrapped round a synchronously revolving drum, precautions being taken to secure identity of movement.

Every worker probably introduces some modification in the apparatus, but little generic alteration need be anticipated. Some may substitute a filings coherer, and others a mirror galvanometer, and the Einthoven galvanometer may be used in various ways as shown in the apparatus used for high-speed transmission and reception in telegraphic work. The value of Mr. Martin's book consists in providing a description of many of the modifications employed, and illustrating these by diagrams which permit the merits and drawbacks to be clearly seen. The directions in which improvements are possible are clearly indicated, and he uses the history of the past to warn others from repeating the mechanism that has been tried and superseded. Undoubtedly, much of the artistic merit in the final result will depend on the fineness of the line-screen used, and on careful manipulation in the early stages. But the degree of fineness of the screen is itself limited by the mechanical efficiency of the entire apparatus, especially in synchronising the sending and receiving cylinders. The limit of error in synchronising should not exceed 1 in 500, in order to produce results suitable for publication, and there is room for the exercise of plenty of ingenuity in securing this degree of accuracy. The author describes the recognised methods for obtaining this degree of delicacy of adjustment and in very considerable detail calls attention to an apparatus, he himself has designed, for ensuring exact duplication at the two stations. Also, he gives a method of transmitting and receiving that after much experience he has found to act most trustworthily. An apparatus usually performs better in the hands of the inventor than in those of others, but Mr. Martin claims that the difficulties of earlier systems have been entirely overcome, and that his device can be worked with ease and satisfaction. Of the latter quality we should have been in a better position to judge if he had given some specimen of his work. We believe that those engaged in similar experiments will be glad to see his method described, and to have the advantage of his long experience. Some very practical hints are included in appendices which are not to be found in the earlier edition, and these, too, should prove of assistance.

Higher Mechanics. By Horace Lamb, Sc.D., LL.D., F.R.S., lately Professor of Mathematics in the Victoria University of Manchester. Cambridge University Press, 1920. [Price 25*s.* net.]

The author is well known as the writer of mathematical treatises, that have obtained a wide reputation and are valued alike by the student and tutor. The present work is an extension (though independent) of similar treatises that have already appeared on statics and dynamics, and exhibits the same refreshing form and stimulating character that distinguishes those works. The book treats of three-dimensional kinematics, statics and dynamics, and Professor Lamb conjectures that the demonstrations will be readily followed by those who are conversant with ordinary two-dimensional mechanics. It is important to note that Professor Lamb has had long experience both as a writer and teacher, and we may conclude that in the works he has written with pedagogic intention, he has indicated the manner in which he considers mechanics should be taught, and the order in which the several subjects should be attacked. Very considerable weight will be attached to his considered opinion, and in the book under review, while introducing some subjects, sufficiently abstruse, the general theory of the differential equations of dynamics is left untouched.

The book claims to be elementary, presumably in the sense that it deals with fundamental principles and treats them concisely, avoiding over elaboration. The student should value this concentration on the fundamental processes, that materially assists the systematic solution of problems. And it is, too, a further pleasing feature that the reader is brought into close contact with the minds that have first pondered over and solved the problems which have perhaps become the commonplaces of modern mathematics. Euler and Poinsot, Hamilton and Lagrange seem very near to us, as we renew acquaintance with principles enunciated by these masters, and we better appreciate the disciplinary value of science teaching when following the pathways that these great minds have explored.

The book opens with a discussion on the several degrees of freedom, leading to an interesting chapter on statics introducing the subject of "null systems" and the theory of screws as developed by Sir Robert Ball. Two well-arranged chapters, concise and pithy, follow on moments of inertia and the instantaneous motion of a body, in the latter of which we meet with a phase of the old problem of the precessional motion in a novel form. Among the illustrated examples is given a discussion of the relation between the angular velocities in a Hooke's joint, affording convincing evidence that while Professor Lamb allows his pupils to wander among the bewildering mazes of "polhode" and "herpolhode," he is willing to apply dynamical principles to human needs and human experience. Gyrostatic problems in which the precession of the Earth's axis naturally occurs, are not discussed till Chapter VIII, where the "intrinsic" equations of the gyroscope are deduced and made to contribute to the solution of a number of problems. The gyrostatic compass and Schlick's device, whereby a flywheel maintained in rapid motion serves to diminish the rolling of a ship, again illustrate the connection between refined mathematical analysis and mechanical handicraft. The aeroplane might have afforded other illustrations, or possibly limitations, to the application of this mechanism. Aircraft, however, is not omitted from consideration. A discussion of the equations which give the conditions for longitudinal and lateral stability is appropriately reserved for the chapter on moving axes.

It is to be hoped that this imperfect catalogue will give some idea of the ground covered, but it would fail altogether to give any idea of the value of the treatise, if no mention were made of the examples and problems attached to each chapter. These problems are distinctly educative; they appear to have been selected specially to illustrate principles and to promote exact thinking. By their use the student can determine whether he has mastered the machinery which analysis provides, as is so ably explained in the text.

BOOKS RECEIVED.

Safety Pamphlet No. 3. The Use of Chains and other Lifting Gears. Issued by the Home Office. London: H.M. Stationery Office. [Price 6*d.* net.]

Bamber's Rubber Calculator Book. In the English and Metric Systems. London: Maclaren and Sons, Limited. [Price 6*s.* net.]

The British in China and Far Eastern Trade. By C. A. Middleton Smith, M.Sc. London: Constable and Co., Limited. [Price 18*s.* net.]

Modern Sanitary Engineering. Part I. *House Drainage.* By Gilbert Thomson, M.A., F.R.S.E., M.Inst.C.E. Second edition. London: Constable and Co., Limited. [Price 16*s.* net.]

History of the Great War Based on Official Documents by Direction of the Historical Section of the Committee of Imperial Defence. Seaborne Trade. Vol. I. *The Cruiser Period.* By C. Ernest Fayle. With case of maps. London: John Murray. [Price 21*s.* net.]

United States Geological Survey. Water Supply Papers. No. 381. *Surface Water Supply of the United States,* 1914. Part I. *North Atlantic Slope Drainage Basins.* [Price 15 cents.] No. 391. 1914. Part XI. *Pacific Slope Basins in California.* [Price 30 cents.] No. 393. 1914. Part XII. *North Pacific Drainage Basins.* (B) *Snake River Basin.* [Price 15 cents.] No. 396. *Profile Surveys in the Colorado River Basin in Wyoming, Utah, Colorado and New Mexico.* Prepared under the direction of W. H. Herron, Acting Chief Geographer. [Price 50 cents.] No. 400–B. *Artesian Water for Irrigation in Little Bitterroot Valley, Montana.* By Oscar E. Meinzer. No. 400–C. *The Measurement of Silt-Laden Streams.* By Raymond C. Price. No. 400–E. *Ground Water for Irrigation in the Morgan Hill Area, California.* By W. O. Clark. Washington: Government Printing Office.

Aeroplane Structural Design. A Book for Designers, Draughtsmen and Students. By T. H. Jones, B.Sc., A.M.I.M.E., and J. D. Fries, A.R.C.Sc., D.I.C. London: Sir Isaac Pitman and Sons, Limited. [Price 21*s.* net.]

United States Bureau of Mines. Bulletin No. 182. *Casing Troubles and Fishing Methods in Oil Wells.* By Thomas Curtin. Washington: Government Printing Office. [Price 15 cents.]

United States Bureau of Standards. Scientific Papers. No. 349. *Air Forces on Circular Cylinders, Axes normal to the Wind, with special reference to Dynamical Similarity.* By HUGH L. DRYDEN. Washington: Government Printing Office. [Price 5 cents.]

Well-Boring for Water, Brine and Oil. A Manual of Current Practice. By C. ISLER. Third edition. Revised and enlarged. London: E. and F. N. Spon, Limited; New York: Spon and Chamberlain. [Price 16s. net.]

Marine Propellers. By S. W. BARNABY, M.Inst.N.A., M.Inst.C.E. Sixth edition, revised. London: E. and F. N. Spon, Limited; New York: Spon and Chamberlain. [Price 24s. net.]

The Motor Trade Telegram Code. Compiled by W. M. SAUNDERS. First edition. London: The Society of Motor Manufacturers and Traders, Limited. [Price 42s. net.]

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ROYAL INSTITUTION.—The following lectures, among others, have been arranged for at the Royal Institution, before Easter: Professor J. Arthur Thomson, a course of lectures on the "Haunts of Life," adapted to a juvenile auditory, to begin on December 30; Sir Gerald P. Lennox-Conyngham, two lectures on the "Progress of Geodesy in India"; Sir James G. Frazer, two lectures on "Roman and English Life"; Dr. W. A. Herdman, three lectures on "Oceanography"; Mr. Frank Balfour Browne, two lectures on "Mason Bees and Wasps"; Dr. George C. Simpson, two lectures on the "Meteorology of the Antarctic"; Dr. Percy C. Buck, three lectures on the "Madrigal," with musical illustrations by the English Singers; Professor A. Fowler, three lectures on "Spectroscopy"; and Sir Ernest Rutherford, three lectures on "Electricity and Matter." The Friday evening meetings will commence on January 21, when Sir James Dewar will deliver a discourse on "Cloudland Studies." Succeeding discourses will probably be given by Sir Frank Benson, Dr. A. D. Waller, Dr. F. W. Aston, Mr. Solomon J. Solomon, Dr. John Buchan, Sir Frederick Bridge and other Gentlemen.

WATER SUPPLY IN RURAL DISTRICTS.—A Chadwick public lecture was delivered on Tuesday, the 7th inst., in the Lecture Room of the Royal Sanitary Institute, by Mr. Alexander Macmorran, K.C., and was entitled "Some Legal Difficulties in Connection with Water Supply in Rural Districts." After examining the duty, or obligation, of Rural District Councils to provide a water supply, the lecturer compared the provisions of the Acts in force before 1875, with those of the Public Health Acts of 1875 and 1878, which give powers to Rural Councils to compel owners of houses to provide water supplies. Points such as the construction of water works, purchase of water in bulk, acquisition of land, taking water from rivers and streams, and many other matters were dealt with from the legal standpoint, and the lecturer concluded by making some valuable and interesting suggestions for amendments of the law in relation to the pressing need for pure and copious water supplies in rural districts. Further particulars of Chadwick public lectures may be obtained from the Secretary, Mrs. Aubrey Richardson, O.B.E., at the offices of the Chadwick Trust, 13, Great George-street, London, S.W. 1.

THE DOXFORD DIESEL ENGINE.

It is with pleasure that we describe and record in this article the constructive features, the trial results and the test bed running of the Doxford opposed piston solid injection two-cycle reversible marine oil engine. To see this large engine, illustrated in Figs. 1 and 2, on page 838, running on its test bed in the makers' works, leaves a most strongly-marked impression of its silence of running, its flexibility and ease of control, only comparable with the most flexible of prime movers—the steam engine. A first impression is further strengthened by the slight amount of steam to be noticed rising from the hot fresh-water outlets from the cylinder and piston jackets. The quality of running of this engine, later more fully to be explained, indicates in fact an important advance in the development of the control of internal-combustion motors. The methods by which this end has been achieved will be described later.

This complete engine represents the culmination of some twelve years of intensive experimental work and research, persistently pursued by Messrs. Doxford. Their investigations have included the building of two single-cylinder experimental engines, to be seen in running condition housed in a test house at their works. The first of these was a single-acting, two-cycle engine with cylinder head scavenging through four valves, and the second an opposed piston engine upon the test results of which the design of the 2,700-b.h.p. unit now under description is very largely and closely based.

First, to describe the engine, the cylinders are designed to develop each a brake-horse-power of 675, and are thus the highest powered cylinders incorporated to-day in a complete multi-cylindered Diesel oil engine. Four such units gives a total brake-horse-power per engine of 2,700. The largest Diesel engine at work is probably the Sulzer two-cycle land type engine developing some 3,000 brake-horse-power in six cylinders, or 500 brake-horse-power per cylinder. The brake-horse-power per cylinder, therefore, developed by the Doxford engine marks in itself an advance.

The dimensions of the engine cylinders are 580 mm. (22⅞ in.) diameter and 2 by 1,160 mm. (2 by 45·6 in.) stroke, divided equally between the upper and the lower pistons. By utilising a high mean effective pressure and the long stroke possible with the principles of opposed piston construction, the power of 675 brake-horse-power per cylinder is attained with a cylinder diameter of only 22⅞ in., as given. For comparative purposes, it can be stated that this cylinder diameter would give, with a normal four-cycle engine, having the usual stroke/bore ratio and piston speed, a brake-horse-power of only some 150 to 170 per cylinder.

The first impression, whether gained from an inspection of the engine or the illustrations, will be that it is very high. When gauged relative to the main connecting rod, this is so; but it must be remembered that the main connecting rod only serves one piston operating through 45·6 in. or half the total stroke. Considering, as is correct, this engine to be virtually of 7-ft. 7-in. stroke, the height is then seen to be proportional to the stroke. In any case, for general marine work, head room is available, and a low engine, unless in exceptional cases, is not required.

There is no need to describe the principle of operation of opposed piston engines, with oppositely-moving pistons, the lower coupled to the central and the upper by side rods to the two outer of the three cranks per unit crankshaft, since this system will be generally familiar. With the opposed piston type of construction there is no cylinder head, the oppositely-moving pistons take the force of combustion upwards and downwards.

Only when utilising the Diesel principle of operation whereby the fuel is not introduced into the cylinder until required for combustion, can the full advantages of the opposed-piston type of construction with its end to end scavenge, be realised. With gas engines constructed on this principle, for instance, not only is pre-ignition somewhat difficult to avoid, but there is always a certain appreciable loss of gaseous fuel through the exhaust ports, so causing a relatively high fuel consumption.

The essential feature of the construction of this type of engine is the cylinder liner, which is a simple tube, grooved, in the case of the Doxford engine, on the outside for water circulation, and provided at the lower end with scavenging air entry ports, giving the air an upward sweep, and at the upper end with exhaust ports well rounded at the corners and designed for strength. This liner, over the working portion of the length is pressed into a water jacket, and in the centre, in way of the combustion chamber has the necessary holes for the two fuel valves and the air-starting non-return valve. At the lower end the liner is pressed into a continuous entablature, forming a scavenging air reservoir and at the top into an exhaust box communicating with the exhaust manifold running the length of the engine. This exhaust box is supported from the entablature by four columns, rendering very accessible the cylinder barrel in way of the combustion chamber as well as the valves these located. This will be clear from the illustrations.

It will, of course, be realised that with the principle of opposed piston there are no tension stresses in the engine framing. The forces consequent upon explosion are contained within, and transmitted entirely by, the forged moving members, the top cross piece, the side rods and the three connecting rods. On the top of the exhaust box are the guides for the top piston. The entablature contains the circular guides for the side connecting rods, and the main columns, four per unit, support the entablature and take the thrust of the main connecting rods. The crankshaft is built up, and the 13 cranks (three for each cylinder and one for the scavenging pump) are carried in six main bearings. These bearings have spherical bushes, and so can oscillate about their centres to accommodate any shaft flexure. The scavenging pump, double-acting with automatic plate valves for the piston, is driven from a central crank, and delivers its air right and left to the entablature reservoir. The air is drawn in through the hood at the top of the pump and enters the hollow piston rod.

The top main piston is coupled to the side rods by a rocking beam with pin points and bearings at both sides. This type of construction allows for any movement of the crankshaft and allows also for differences in length and setting of the side rods. Both the main pistons are easily accessible, the upper drawn up, after the dismantling of the two guides and disconnecting the side rods, and the lower drawn down into the large crank chamber when the middle and main crosshead is dissembled.

The valve gear is simple, because of the reduction of the numbers of valves per cylinder to the minimum of two fuel injection valves, one at the front and one at the back, one non-return air-starting valve and one safety valve. There are two cam shafts, one at the back serving to drive indicator gear, "vacuum" type force-feed lubricators for the cylinders, and the four fuel valves, and one at the front for the four fuel valves and starting air valves. These two cam shafts have separate drives by spiral gearing from the crankshaft. For astern running it is interesting to note that only the front cam shaft and fuel injection valves are used. It is generally preferred in order to obtain accuracy of cylinder indicator diagrams, to drive the indicator from the engine crosshead. In this case, although the cam shaft is used, special cams and motion gear have been designed accurately to represent the piston motion.

Reversal is effected by rotating by means of the large hand wheel, the usual valve lever fulcrum shaft upon which the various fuel and starting air-valve levers are eccentrically mounted, and when this rotation lifts the rollers from off the cams, the cam shaft, by means of a hand lever, is shifted fore and aft, so bringing into position the cams for fuel injection and starting air valves for the reverse direction of rotation. Further operation of the fulcrum shaft, brings into play the four starting air valves, and then the four fuel valves. The fuel pumps are grouped together and are of massive forged-steel construction, suitable for the full-power working fuel pressure of about 10,000 lbs. per square inch. The drive is unusual, but is quite rational when the delivery pressure of 10,000 lbs. per square inch is considered; it is from a spur wheel seen in Fig. 1, keyed on the main shaft at the after end of the engine. These pumps deliver to a junction box on the column abaft the starting position when the four deliveries can be connected up, giving the so-called "common rail" system, which is the system generally adopted for this engine, or alternatively each pump can be conducted to its own cylinder, so enabling a defectively-working pump or fuel valve to be readily isolated. The common rail system whereby all the deliveries from the pumps are connected, gives a steady pressure and tends to ensure equal power per cylinder. These pumps are controlled in the usual way by the holding open of the suction valves for a longer or shorter period of the pump revolution, either from the hand wheel or from the Aspinall emergency governor. Since this design will be installed as a single-screw unit, an interesting provision has been made. Adjacent to these fuel pumps and separately driven is an exactly duplicate set, which can immediately be set in motion and coupled up by one pin to the main engine control gear, so that the most vital unit in the engine, if working defectively, can immediately be cut out, and its duties taken up by this spare set. This provision is a good example of the care and foresight displayed in the design of this plant.

The designers of this engine have adopted a new system of engine cooling. The ribs in the liner already referred to enable the liner thickness to be decreased by giving support, from the cylinder itself, against internal pressure and also increase the velocity of

THE TURBINE YACHT "CUTTY SARK."

CONSTRUCTED BY MESSRS. YARROW AND CO., LIMITED, ENGINEERS, SCOTSTOUN.

(*For Description, see opposite Page.*)

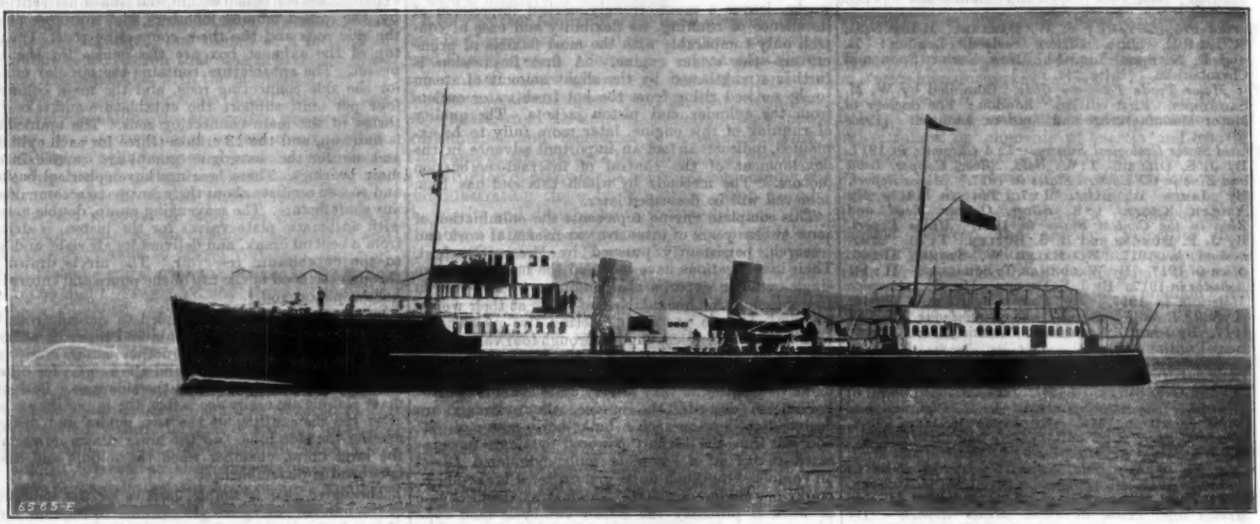


Fig. 1.

flow of the cooling medium; but the chief interest is centred in the use of fresh water for the piston as well as for the cylinder cooling. This water is supplied from a separate pump in a closed system with a salt-water cooler in the circuit. The use of fresh water admits of a much higher temperature being carried in the pistons and cylinders, than would be permissible with sea water, due to the risk with the latter, of the deposition of salt, when quite a moderate temperature is exceeded. The separate discharges from each piston and cylinder, led into funnels at the front of the engine, all provided with thermometers, recorded at full power a temperature of from 150 deg. F. to 160 deg. F. The water is led into both the top and bottom pistons by swinging pipes and rotating joints. Slight leakage of this fresh water at one of the joints from the forward engine lower piston was noticeable. The tops of the main pistons are of unique design, containing as they do forged steel blocks, designed so as to retain heat. Preliminary heating of the jackets by steam from a donkey boiler is necessary prior to the initial starting of the engine on heavy fuel oil.

The whole of the main bearings are force-lubricated, as is now generally recognised as absolutely essential for Diesel engines, and the supply of oil is arranged from separate pumps. The pressure carried is from 12 lb. per square inch to 14 lb. per square inch. The whole engine when running is completely enclosed by light steel plate doors provided with smaller and easily removed doors for the quick examination of any bearing. The design of these doors is efficient, and the leakage of lubricating oil during the trials, it is pleasant to be able to record, was negligible.

To consider in detail the running of this interesting Diesel engine. Due to the opposed pistons conferring advantages of rapid compression, to the initial heating of the jackets by steam, the solid steel block on the top of each piston, and the system of solid injection of the fuel, the engine is started very readily with starting air at low pressure. The maximum pressure of starting air is 500 lb. per square inch, and since no air is used to assist the injection of the fuel into the cylinders, there is no compressor on the main engine; a separately driven auxiliary for starting air is provided. When the engine fuel system is primed, one revolution on starting air suffices to give sufficient momentum so that, the four fuel valves being immediately cut in, combustion commences and normal running ensues. The flywheel fitted is of very moderate dimensions when the low normal speed of revolution of 77 revolutions per minute is considered.

As an instance of flexibility, the engine was, during the trials, run against suitable load on the water brake at less than 20 revolutions per minute, firing with perfect regularity on all cylinders and with a clear exhaust, without any manipulation of the control levers to maintain continuity of running. This speed was maintained for periods of over a quarter of an hour, without a misfire, and could have been maintained indefinitely. This performance will be fully appraised when it is realised that at low loads the lift of the cylinder head fuel valves is little more than one-hundredth of an inch. The ratio of 77 to less than 20 revolutions per minute, or 4 to 1, is very exceptional for a slow-speed engine, and has not, so far, to our knowledge, been previously recorded. It is possible that with a larger flywheel a lower speed could be attained if desired.

At 20 revolutions per minute the momentum effect of the flywheel was negligible, the rotation of the engine being perceptibly jerky, the engine just passing the dead centres. At this speed the piston velocity is only a mean of 150 ft. per minute. The factors contributing to the performance are the even turning moment of the opposed piston engine, the solid injection of the fuel, the hot piston top, the hot fresh water circulation of the jackets, the efficient design of the fuel injection valves and their nozzles, and the fine adjustment of the gear whereby at reduced loads the time and amount of lift of the cylinder fuel valve can so accurately be adjusted to the required minimum. Moreover, due to the method of retaining the heat of combustion, and to solid injection, the normal compression pressure is much lower than the average Diesel figure, and is of the order of 300 lb. per square inch.

At over-speed the Aspinall governor, driven from a lever off the crankshaft, cut in and out, controlling definitely and regularly fuel supply from the fuel injection pumps, even when the engine was set for full power, and all load was removed for a period.

At full power the engine ran steadily and without vibration, the usual test of standing a penny on edge on the top of the engine being successful. The only time that the exhaust was visible was on one occasion when changing speed rapidly, a whitish-blue smoke was for a moment emitted.

The full-power rating of the engine is 2,700 brake horse-power, which, at 77 revolutions per minute and with the dimensions given, works out at a piston speed of 585 ft. per minute and a mean effective pressure, on a brake horse-power basis, of 93 lb. per square inch, a high figure with a clear exhaust for two-cycle engine, made possible by the end-to-end scavenge through the long cylinder obtainable with the opposed piston design. The scavenging air pressure at full power was 2 lb. per square inch. The mechanical efficiency of this engine will be high. The lubricating oil, cooling water, sea water and other pumps are separately driven. The compression pressure is low. The fuel used on these tests was a Mexican heavy oil, with 22 per cent. asphalt and of the low calorific value of 17,600 B.T.U.'s per lb. With oil of high heating value the consumption is of the order of 0·42 lb. per brake horse-power per hour. The engine was, as we have stated, remarkably silent. The only, and just distinguishable, noises were the hiss of the scavenging air intake and the gear driving the fuel pumps. The absence of the usual valves contributes most largely to this result. The exhaust, not easily silenced with two-cycle engines, was particularly well muffled.

One or two words of criticism may be offered. Whilst the ladders and gratings provided are ample for shop purposes, and are generally all-sufficient (for instance, there is a grating inside the crank chamber for access to the crossheads), yet for marine work additional guards and handrails are required for absolute safety when in a seaway men are on the top platform. Furthermore, the design of the gear on the top, more particularly the water cooling leads to the top pistons, will no doubt be given increased clearances to lessen risks. The somewhat trivial nature of these adverse remarks indicates the most excellent impression made by the engine.

The engine with which we have been dealing is undergoing a series of exhaustive trials before being fitted on board. A number of similar engines are being built for installation as single-screw units in sister vessels, and the first of these, the Yngaren, of 430 ft. length by 54 ft. beam and 25 ft. 6 in. draught, is already launched.

All the auxiliaries will be electrically driven, with current supplied from three 70-kilowatt two-cylinder Doxford opposed trunk piston Diesel engines with cylinders 7 in. diameter, driving direct-current generators. These auxiliary engines, three for each ship, therefore, closely resemble the main engine in all the essential features. We look forward to publishing later in full the results of the further trials of this most interesting engine in the shops, as well as in the ship at sea.

The Celluloid Industry.—According to Dr. F. Sproxton (Journal of the Society of Chemical Industry, October 30), Great Britain alone of the allied countries was able to supply celluloid at the outbreak of the war. The demand for celluloid, as a substitute for ebonite, glass, metals and wood, rapidly assumed surprising dimensions; cutlery handles, pumps, mudguards, windscreens and other motor and cycle accessories; telephone mouthpieces; eyelets for boots; accumulator cases being among the many celluloid articles wanted. In the manufacture of celluloid dried nitro-cellulose from paper, is worked into a jelly with camphor and alcohol; the pigments and dyes are then added, and the material is manipulated on hot rollers and pressed into blocks or extruded; the blocks are sliced on planing machines, and the sheets are seasoned in stoves to drive off the excess solvent. The celluloid of kinematograph films burns so fiercely because it contains a highly-nitrated cellulose. A substitute for camphor has not yet been found. Cellulose acetate, an acetyl cellulose dissolved in acetic acid, can compete with celluloid in some fields, but is less uniform because the temperature control of the very viscous solution is difficult. The material is less tough than celluloid and more expensive on account of the acetic acid; it is valuable as a base of aeroplane dopes since it draws the fabric taut, and is preferred for these uses because it is non-inflammable.

THE TURBINE YACHT "CUTTY SARK."

CONSTRUCTED BY MESSRS. YARROW AND CO., LIMITED, ENGINEERS, SCOTSTOUN.

Fig. 8. FRAME 113. LOOKING AFT.

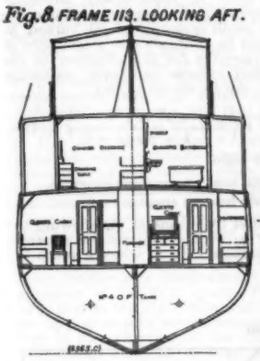


Fig. 9. FORECASTLE DECK.

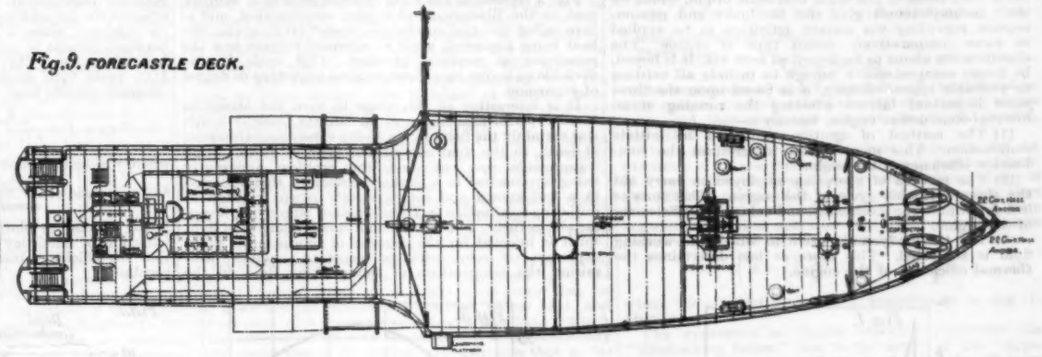


Fig. 12. FRAME 46. LOOKING FORWARD.

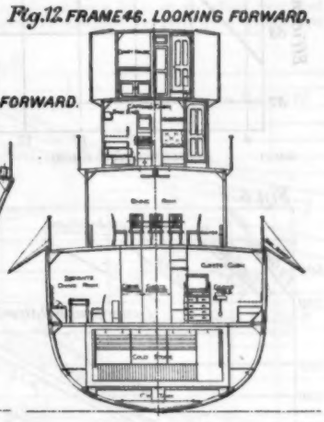


Fig. 11. FRAME 16. LOOKING FORWARD.

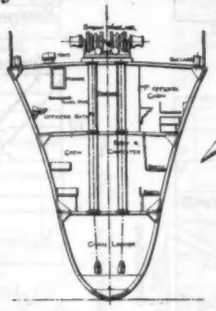
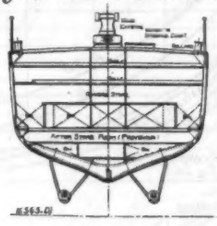


Fig. 10. FRAME 140. LOOKING AFT.



THE photographs and drawings reproduced on this and the opposite pages, and on Plate LXXIV, which accompanies this issue, illustrate a somewhat unusual type of vessel recently constructed by Messrs. Yarrow and Co., Limited, of Scotstoun, Glasgow. It is a steam yacht named Cutty Sark, and it was designed and built by the firm for Major Henry Keswick, of Dumfries. From the half-tone engraving, Fig. 1, on the opposite page it will be seen that the vessel bears a close resemblance to a modern destroyer and the hull is, in fact, exactly similar in form to many destroyers built by Messrs. Yarrow during the war.

The length of the vessel is 273 ft. 6 in. overall and the beam is 25 ft. 7½ in., the Thames Yacht tonnage being 857·5 and the contract speed 20 knots. She is propelled by two sets of compound impulse turbines, also constructed by Messrs. Yarrow, each driving a separate propeller through single-reduction gearing. As the Cutty Sark is intended to be used for long voyages, both high-pressure and low-pressure turbines, and their nozzles have been designed with a view to obtaining the maximum economy in fuel consumption and the results obtained on trial, we understand, have more than satisfied the owner in this and all other respects.

The general arrangement of the machinery is shown in Figs. 2 and 4, and also in Figs. 6 and 7, on Plate LXXIV. Steam is supplied by two Yarrow water-tube boilers arranged for burning oil fuel on the Yarrow system. They work under forced draught and are placed in a single boiler-room having a common stokehold in which two main and one auxiliary feed pumps are also mounted. The oil-fuel heaters, and two fan engines, the latter clearly shown in Fig. 6, are also placed in the stokehold. The condensers, which are of the Weir "Uniflux" underslung type, with riveted steel bodies and brass tubes and tube plates, are shown in Figs. 2 and 7. Two Dual air pumps, an evaporating and distilling plant, two forced lubrication pumps, and two circulating pumps are also fitted in the engine-room, and the auxiliary machinery also includes a fire and bilge pump, a centrifugal pump for salt water service, a direct-contact feed heater and two electric lighting sets, one of which is driven by a steam engine and the other by an oil engine.

The trials which were carried out in the Firth of Clyde, were entirely satisfactory, the fuel consumption at all speeds being lower than was anticipated. The mean speed on the Admiralty deep-water mile at Skelmorlie was 21·63 knots, and at this speed the mean propeller revolutions were 409 per minute The steam pressure at the boilers was 225 lb. per square inch, and at the high-pressure turbine nozzles 160 lb. per square inch. The vacuum was 28·7 in. of mercury and the air pressure in the stokehold 2⅜ in. of water. On the cruising trials a mean speed of 15·26 knots was obtained with the propellers running at 288 r.p.m., the steam pressure at the turbine nozzles then being 150 lb. per square inch and the air pressure in the stokehold 1½ in. of water.

The owner's accommodation consists of a suite of rooms in the after deck-house, shown in the plan, Fig. 3 and includes two bedrooms, and two sitting rooms, with bath rooms and lavatories. Aft of these rooms is the entrance hall, or lounge, adjoining which is a shelter open at the after end. Over this deck house, which is 54 ft. long, is a promenade deck. From the entrance hall a staircase leads to the lower deck, where there is a boudoir, and also four guests' cabins, each with its separate bathroom and lavatory. In the forward deck house on the main deck is the owner's dining room and smoking room. A corridor arranged on the starboard side through the machinery spaces provides communication between the accommodation aft and the accommodation forward for the owner's use in bad weather. This corridor is fitted with a watertight door at each end. At the forward end of the corridor there are three more guests' cabins with two bathrooms and lavatories. Forward of the machinery spaces are the crew's galley, owner's galley, cook's pantry, servants' mess-room, and cabins for the chief steward and chef. A drying room is fitted with steam-heating and an exhaust fan, and there is also a refrigerating machine and a cold-store room. The officers' and crew's quarters are arranged in the fore-castle as shown on the deck plans, Figs. 3 and 4, on Plate LXXIV. Above the owner's dining room is the captain's cabin, wireless office, and the observation room shown in the plan, Fig. 9, on the present page, and over these again are the chart-house and navigation bridge, a plan of which is given in the top right-hand corner of Plate LXXIV. A transverse section through this part of the ship is shown in Fig. 12 on the upper part of this page.

The owners' and officers' quarters are finished in mahogany with light wood panelling, and care has been taken to avoid all corners where dust or moisture might collect. Double awnings are provided over all living spaces with side curtains to the gunwales as shown in the cross-sections, Fig. 7, on Plate LXXIV, and Fig. 8 on the opposite page. There is a complete system of hot and cold sea-water supply, in addition to hot and cold fresh water in the bath rooms, and two fans and a system of trunking are fitted, to supply hot or cold air in addition to natural ventilation. Steam and electric radiators are fitted in the living spaces. The vessel is lighted throughout by electricity, current being supplied by the steam and oil-driven dynamos previously mentioned.

The fuel capacity is such that the vessel can steam 5,500 nautical miles at 15 knots without refuelling, or about 7,000 miles at 12 knots. She has already steamed a considerable distance, encountering moderate seas at times, and the owner has expressed his complete satisfaction with her performance.

THERMODYNAMIC CYCLES OF INTERNAL-COMBUSTION ENGINES.

*Thermodynamic Cycles in Relation to the Design and Future Development of Internal-Combustion Engines.**

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1. *Introduction.*—The notes comprised in the paper to be given here represent an endeavour to place upon a practical working basis the application of thermodynamic theory to the science of internal-combustion engineering. This particular branch of engineering has, of recent years, outgrown most others, one might say, in the interest and fascination of its accompanying problems. It is hoped therefore, that little apology is required for giving some attention to a discussion of the more or less theoretical aspects of the subject, both from the point of view of possible future development and from the standpoint of design.

The main portion of the paper, embodying the result of perhaps much one-sided concentration, is based upon a fairly wide experience gained while carrying out tests on practically all kinds of internal-combustion engines, including those operated by coal-gas and producer-gas, oil engines of the Diesel and so-called semi-Diesel types, the hot-bulb oil engine and also high-speed petrol engines of the automotive class. It is but natural that constant association in this way with one particular branch of engineering should give rise to a gradual formation of ideas regarding the many and various questions which continually compel the attention of those engaged on such duties. Inevitably, perhaps, many controversial points are raised, but at the same time it is hoped that some order has been restored to a subject which suffers at present from some lack of co-ordination.

The outstanding feature in the thermodynamics of the internal-combustion engine, distinguishing it sharply from that associated with steam-engine practice, is the necessary inclusion of the variable specific heat factor in all fundamental analyses. Another point of difference (this opinion will probable be questioned) is that relatively little advantage is derivable from any application of the "entropy" function to the discussion and elucidation of the phenomena involved. Accordingly no attention is given here to such application.

2. *Classification of Engine Types.*—Some classification of the various existing and proposed types of engine will be attempted first in order to prepare the way for the subsequent portions of the paper. Classification of some kind, of course, is necessary in any subject which is to be studied with any presumption to scientific method. At the present time, owing to the somewhat chaotic state of internal-combustion engineering nomenclature, this classification has become a matter of no little difficulty. Such terms as "cycles of operation," "method of operation," semi-Diesel, &c., are used with little or no definite meaning. Terms on a par with the last given are often employed in describing some particular type of engine, but any indication of the principles on which the engine is operated will be looked for in vain in the particular term used. This confusion, arising as it has, out of the prevailing multiplicity of

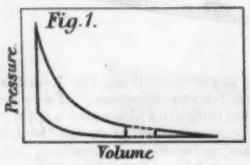
* Paper read before the Institution of Mechanical Engineers, December 17, 1920.

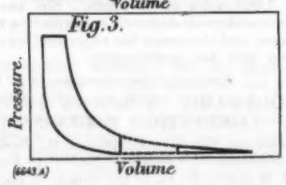
engine types, may not cause much inconvenience to those engineers well versed in modern practice. At the same time, however, it has been the author's experience that to have an orderly and at the same time thorough grasp of the subject, some classification is very necessary other than those of the usual text-book origin, which by their incompleteness give rise to doubt and misconception regarding the correct definition to be applied to some comparatively recent type of engine. The classification about to be described here will, it is hoped, be found comprehensive enough to include all existing or probable types. Briefly, it is based upon the three most important factors affecting the running of an internal-combustion engine, namely :—

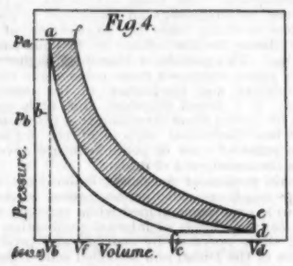
(1) The method of ignition employed to initiate combustion. This more or less determines the combustion efficiency of the engine.

(2) The method of operation employed to carry out the thermodynamic cycle of the engine. This more or less determines the mechanical and volumetric efficiencies of the engine.

(3) The thermodynamic cycle to which the working fluid is subjected. This more or less determines the thermal efficiency of the engine.







The first distinguishing factor, the method of ignition, may be classed under four heads, according as the combustion is initiated by—

(*a*) Surface combustion.
(*b*) Electric spark.
(*c*) High compression.
(*d*) Flame injection.

It is interesting to note that (*a*) includes the earliest and also one of the latest methods of ignition, namely, the hot incandescent tube of early gas-engine days, and now the well-known "hot-bulb" of a type of oil engine which has come recently into favour for certain classes of work ; (*b*) requires no comment, and (*c*) is, of course, the achievement of Diesel ; (*d*) represents a method of ignition which has had little serious development, but it possesses an interest of its own to which reference will be made later.

The method of operation given as the second distinguishing factor, includes only the two well-known four-stroke and two-stroke methods. The probability of others displacing these appears at the present time very remote.

Figs. 1 to 3 have been drawn to illustrate the classes into which the third distinguishing factor, the thermodynamic cycle, may be divided. Thus in Fig. 1, the full-line diagram to the left represents the constant volume combustion cycle (C.V. cycle) with compression volume expansion. This is the standard cycle for most modern engines. With the dotted portion of the diagram included in the full-line left-hand portion, the figure represents the C.V. cycle with extended expansion. So far as the author is aware there are no engines in existence operating on this cycle at full load. The entire diagram represents the C.V. cycle with complete expansion. This is the cycle of the well-known Atkinson engine and also of the Humphrey pump.

Similarly Fig. 2 represents the constant pressure combustion cycle (C.P. cycle) with the same three divisions according to expansion. The first division represents the Diesel engine cycle, the second has no counterpart in past or existing practice, while the third is typified by the Brayton gas-engine cycle.

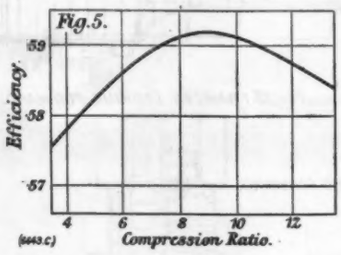
Fig. 3 represents the class of cycle on which engines, such as the Blackstone oil engine, are operated, and is here called the dual combustion cycle* (D.C. cycle), the heat being imparted, some at constant volume and the remainder at constant pressure. This cycle is also divisible as before into three sections according to degree of expansion.

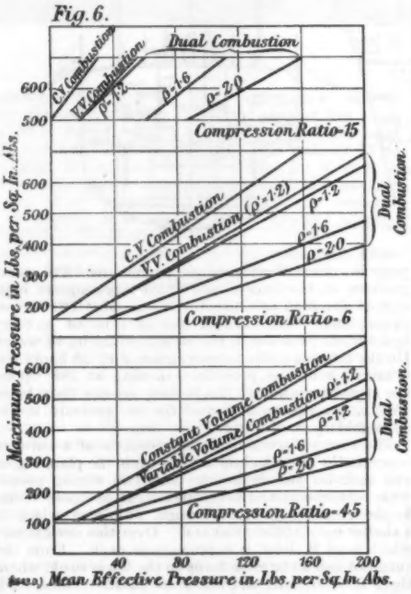
It is interesting at this stage to turn the attention to an experimental engine of Sir Dugald Clerk's† which was certainly the first, giving a very close approximation, at least, to the dual combustion type of cycle. High compression was not used, the problem apparently being approached in a similar manner to that followed in a well-known and comparatively recent method of initiating combustion in Diesel engines employing heavy tar oils as fuel. In this method a small quantity of light spirit is injected for the purpose of producing a slight explosion or combustion at constant volume, thus raising the temperature of the working fluid to the additional degree necessary to burn, at constant pressure, the heavy tar oil injected later. In the Clerk engine air only was compressed as in the Diesel engine, but the compression being low the temperature was not sufficient to initiate combustion when the compressed gas was injected, so a flame jet was used, this flame jet performing the function of the small quantity of light spirit in the type of Diesel engine already considered. This was the first successful attempt to employ the flame injection method of ignition.

Other engines which are operated approximately on the dual combustion principle are the Sabathé engine, the De La Vergne engine and the Trinkler-Körting engine.‡

3. *Combustion Processes.*—It is well at this juncture to define certain quantities involved in the different cycles, particularly those quantities relating to the combustion processes. Since the combustion processes, in which present-day engineers are almost wholly interested, are those taking place either at constant volume or at constant pressure, it will be convenient to refer to those processes here in terms of two quantities which are defined as follows :—

(1) The ratio of the pressure at the end to the pressure at the beginning of constant volume combustion. This ratio is denoted by α.





(2) The ratio of the volume at the end to the volume at the beginning of constant pressure combustion. This ratio is denoted by ρ.

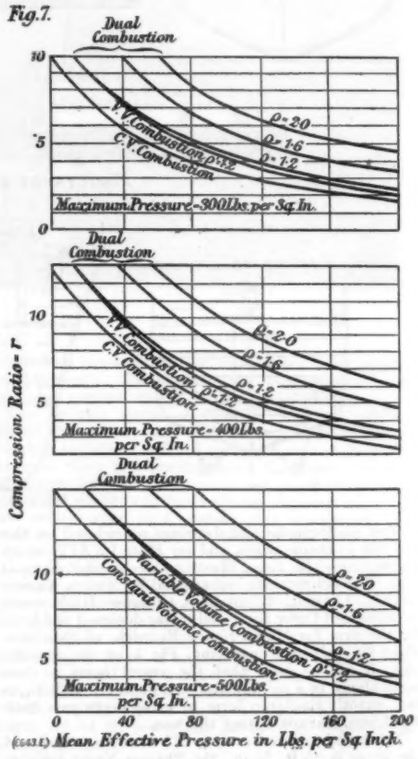
A misconception* to which attention may be drawn here is the impression that the efficiency of the constant pressure combustion cycle is, theoretically, adversely affected by the addition of heat at constant volume, as, for instance, when a small quantity of oil burned at constant volume is used to facilitate the combustion of heavy tar oils. The formula for the efficiency of the D.C. cycle with suction volume expansion, assuming constant specific heat, can be shown to be†

$$\eta_d = 1 - \frac{1}{r^{\gamma-1}} \left\{ \frac{\alpha \rho^{\gamma} - 1}{\alpha - 1 + \gamma \alpha (\rho - 1)} \right\} \quad . \quad (1)$$

where r = compression ratio

and γ = ratio of $\frac{\text{specific heat at constant pressure.}}{\text{specific heat at constant volume.}}$

If the curves are plotted by means of (1) showing the variation of efficiency η_d with α, it is readily apparent that the efficiency increases with α, when r and ρ are constant.



The point may be raised, of course (and generally is), that the basis of equal compression ratios is not a fair one for purposes of comparison. It is justly claimed that the basis should be that of equal maximum pressures. Even conceding this, however, it does not appear that there is any reason to condemn the introduction of additional combustion at constant volume into a cycle in which fuel is burned at constant pressure. Thus, in Fig. 4, the shaded area $a\,d\,e\,f$ represents a normal Diesel engine diagram. This is compared with the complete figure $a\,b\,c\,d\,e\,f$ representing another cycle of the same maximum pressure, but with a lower final compression pressure, combustion being initially carried out at constant volume to give an explosion pressure equal to the final compression pressure of the first cycle. It should be observed that this second cycle is the D.C. cycle with extended expansion. The efficiency expression for this has been obtained and is given in another paper.‡ It is sufficient to state here that the maximum efficiency condition of the cycle is given by

$$(\gamma - 1)\, r^{\gamma} - A\, r^{\gamma - 1} + B = 0 \quad . \quad . \quad (2)$$

where A and B are constants.

Assuming that the maximum pressure is determined by $r = 13$ in the true Diesel cycle, the compression ratio giving maximum efficiency is found by means of (2) to be somewhere about 9 when $\rho = 2$. This gives a value of α of 1·7. The variation of efficiency with compression ratio is given in this case by Fig. 5, where the maximum point is evident. Also, the higher the value of ρ, the lower is the compression ratio giving maximum efficiency. It thus appears that the efficiency of Diesel engines may be increased by diminishing the compression ratio and

* *The Automobile Engineer*, January, 1918. Paper on "Thermodynamic Cycles."

† "The Gas, Petrol and Oil Engine," Clerk and Burls, vol. ii, pages 264 to 269.

‡ Proceedings, Am.Soc.M.E., 1911.

* *Internal-Combustion Engineering*, 1914, page 286.

† *The Automobile Engineer*, January, 1917.

‡ "A New Thermodynamic Cycle," ENGINEERING, vol. 109, page 467, April 9, 1920.

introducing additional combustion of fuel at constant volume as in the extended expansion cycle of Fig. 6.

It is claimed, however, on behalf of the Diesel cycle, that its efficiency is in some measure due to the fact that the quantity of air necessary for the combustion of the fuel injected at maximum load is always appreciably less than that actually present in the cylinder. The claim certainly has some truth in it, but nevertheless has nothing to do with any really inherent advantage to be derived from the use of so-called weak mixtures. It is well-known that the fundamental theory of the Diesel cycle shows that high efficiencies are to be realised with small values of ρ, and that if the mixture is to be strengthened (that is, if ρ is to be increased) the efficiency of the cycle must suffer. That fact, however, is no proof that richer mixtures may not be thermodynamically advantageous for use in other cycles. It is evident, of course, that in the D.C. cycle of Fig. 4 (page 848), a richer mixture must be used than in the corresponding Diesel cycle shown. Were it desired, however, to burn the same quantity of fuel per pound of air in the Diesel cycle as in the D.C. cycle, the efficiency of the former would suffer to an extent which would render it very much further at a disadvantage in comparison with the efficiency of the D.C. cycle. Flame temperatures will be higher in the D.C. cycle, but the extent of these does not appear to offer any insurmountable difficulties in the way of the adoption of the cycle. There are besides, well-known methods of keeping down flame temperatures.

It may be considered that all that has been done in evolving this cycle is to continue further the expansion of the original D.C. cycle with compression volume expansion. This has already been suggested and carried out by several inventors, notably Atkinson, with the object of increasing the efficiency of the Otto or C.V. type of engine. That the efficiency would be increased is obvious, but the point to be noted is that either constant volume combustion or constant pressure combustion alone do not yield a maximum efficiency cycle at a medium compression ratio such as is given by the dual combustion method. The reason why such additional expansion has received little serious attention is due to the appreciable diminution in mean effective pressure which accompanies its adoption in the C.V. and C.P. cycles. This objection does not hold to the same extent in the D.C. cycle.

The high compression of the Diesel cycle is the main objection to its use for automobile and aero engines. The D.C. cycle offers a method of obtaining high efficiencies without the excessive compression ratios of the Diesel engine.

4. *Variable Specific Heat.*—The question as to how much of the variability of specific heat is apparent and how much is real does not greatly matter for present purposes. Some is probably due to real variable specific heat, some to cooling, a little to after-burning, and still less to dissociation. The experimental values available do not agree very well amongst themselves. The tendency at first was to look upon specific heat as varying with temperature. Later the B.A. Committee on Gaseous Explosions recommended that a term involving the square of the temperature be included. Values due to Pier and Bjerrum,* are, however, now available which throw considerable doubt upon the validity of the assumption that the temperature-squared term possseses any great importance. The internal energy curves deduced from Pier and Bjerrum's figures have very much less curvature at temperatures over 3,000 deg. C. than those of the late Professor Hopkinson's as deduced from B.A. values for specific heat. It is considered that for all practical purposes it is sufficient to formulate the closely approximate law that "the "apparent" specific heat varies directly with temperature." This assumption is in close agreement with the facts as given above. The inclusion of another term involving the square of the temperature is probably quite unnecessary for practical purposes.

The value of the factor which gives the rate of change of specific heat with temperature is obviously one which can be determined only by reference to the results of engine and explosion vessel tests.

In this connection it is important to inquire briefly into the effect of engine speed and conductivity of cylinder walls upon this apparent specific heat factor by noting their effect upon engine efficiency.

As recent experiments have shown, both on air-cooled and water-cooled engines of the high speed type, the actual thermal efficiency on brake horse-power lies, for all good designs, somewhere between 25 per cent. and 35 per cent. with compression ratios varying from 4·5 to 6. This compares well with the efficiency of the stationary slow speed gas or oil engine, and indicates that so far as thermal efficiency is concerned, the speeds of operation so far employed have little or no effect, provided that the engine is designed to give good volumetric and mechanical efficiencies. The independence of brake thermal efficiency upon speed has been very clearly demonstrated by this high-speed petrol-engine experimental work. There seems to be but slight departure from accuracy, therefore, in stating that—the brake thermal efficiencies actually realised, approach, according to perfection of design, to a theoretical maximum, which is identical for all types of engine operating on the same thermodymamic cycle, and is independent of engine speed.

In the case of the conductivity of the cylinder walls it has been found that the effect of low conductivity or bad cooling is to diminish the thermal efficiency on brake horse-power. This is clearly brought out in comparing tests of air-cooled engines with cast-iron and aluminium cylinders respectively. In every case, however, investigation shows that this diminution in brake thermal efficiency is due wholly to a diminished volumetric efficiency. When allowance is made for this diminution in volumetric efficiency, both the indicated and brake thermal efficiencies of both types are found to be practically identical. Hence it may be enunciated that—provided that the conductivity or the effectiveness of the cooling system does not affect the volumetric efficiency to any appreciable extent, its effect upon brake thermal efficiency is negligible.

According to the usual notation the formulæ expressing the relationship between specific heat and temperature are generally given as follows:—

$$K_p = A + S\,T + S'T^2$$

$$K_v = B + S\,T + S'T^2$$

where A, B, A and S′ are constants and T is absolute temperature.

The ratios $\frac{S}{B}$ and $\frac{S'}{B}$ will be denoted by the symbols λ and λ'.

The numerical value in foot-pounds units adopted by the author for the constants in the above formula, as conforming closely to generally accepted engine and explosion vessel tests are as follows:—

$$K_p = 317 + 0.0623\ T \text{ ft.-lb. per lb. per deg. C.} \quad . \quad (3)$$

$$K_v = 220 + 0.0623\ T \text{ ft.-lb. per lb. per deg. C.} \quad . \quad (4)$$

λ' being considered negligible.

From (4)

$$\lambda = 0{\cdot}000283.$$

The acceptance of such figures can only be claimed on their agreement with values already obtained in engine tests, and this agreement appears to be, in general, fairly close.

The following formula has been obtained by an extension of an analysis* already given in another paper. If η' represents the theoretical thermal efficiency of any of the different classes of C.V., C.P. and D.C. cycles, then the indicated thermal efficiency to be expected from engines in practical operation will be given in each case to a first and close approximation by

$$\eta = \eta' \left\{ 1 - \left(\frac{\lambda' T_a^2}{2} + \lambda T_a \right) \left(\frac{a + \rho}{2} \right) \right\} \quad . \quad (5)$$

where T_a = initial compression temperature in deg. C. absolute.

The expression in double brackets represents the "diminishing factor" due to the action of the "apparent" variability of specific heat, η' being the efficiency of the cycle under constant specific heat conditions.

5. *Relations between the Mean Effective Pressures, the Maximum Pressures and the Efficiencies of the Various Cycles.*—The variable specific heat expressions giving the relations between the mean effective pressures, the maximum pressures and the efficiencies are somewhat lengthy, and for that reason are not stated here.

Figs. 6 to 10 have been plotted by means of the formulæ thus derived, giving the relationship between the most important quantities with which engineers, specialising in internal-combustion work, are intimately concerned. The graphs given there have been subjected to a good deal of practical application and have been found to approach as near to the truth as it would appear to be possible to arrive in any theoretical treatment of the subject.

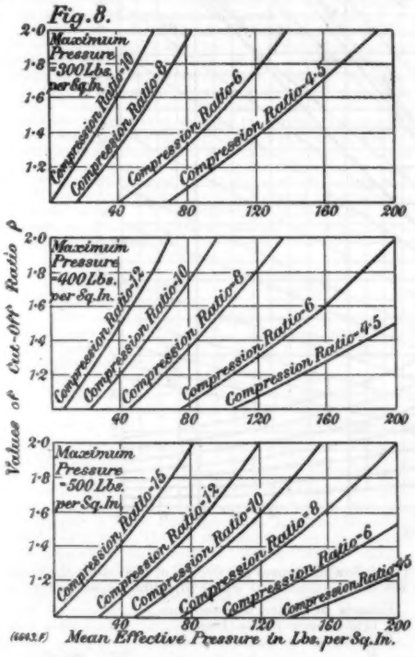
Referring first to Fig. 6, it will be observed that five different cycles are concerned, all of the incomplete expansion type of present-day practice. The first is the usual C.V. cycle. The second is what may be called a variable volume cycle (V.V. cycle) and is represented by such a diagram as is given in Fig. 12 (page 850), in which the combustion line, instead of being vertical, leans over somewhat to the right as shown there. Here some further explanation is necessary. The symbol ρ' in this cycle chosen as 1·2 in the example given, is the ratio:—

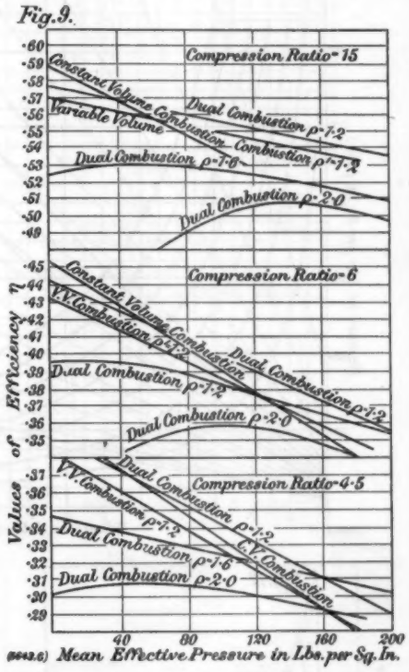
$$\frac{\text{Volume at end of combustion}}{\text{Volume at beginning of combustion}}$$

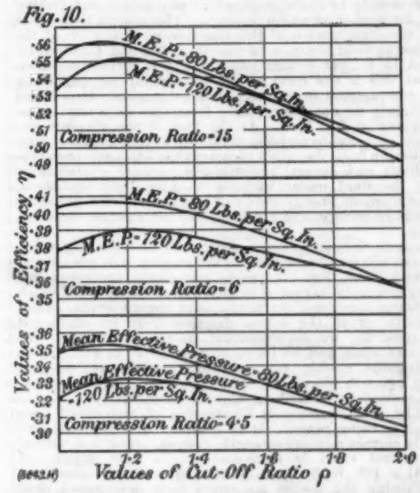
The third, fourth and fifth cycles are of the dual combustion type with $\rho = 1{\cdot}2$, 1·6 and 2 respectively.

It is interesting to observe from Fig. 6 how the maximum pressure of a cycle is diminished for the same mean effective pressure when the constant volume combustion process is slightly departed from to give a value of 1·2 for ρ' in the V.V. cycle. Fig. 9 (above) shows also that for this degree of departure from the standard C.V. cycle, the V.V. cycle actually has a higher efficiency under certain circumstances. This result is surprising, but close investigation into the matter has failed to indicate any error in the analysis or the calculations involved. The main reason for this was then seen to lie in the lower maximum temperature of combustion in the cycle with the sloping combustion line, so that the loss (according to constant specific heat theory) due to departure from constant volume combustion conditions is more or less counterbalanced by the diminution of the loss due to the variable specific heat.

Fig. 7 gives the relationship between the mean effective







* *Zeit fur Elektrochem.*, 1909, vol. xv, page 536; 1910, vol. xvi, page 897; 1911, vol. xvii, page 731; 1912, vol. xviii, page 101. *Zeit fur Phys. Chem.*, 1912, vol. lxxix. See also *The Automobile Engineer*, February, 1920, page 57.

* *Philosophical Magazine*, September, 1917.

pressures and compression ratios of all the cycles, when the maximum pressures are respectively 300 lb., 400 lb. and 500 lb. per square inch absolute.

Fig. 8 shows, for different compression ratios, the variation in m.e.p. with the cut-off ratio ρ of the D.C. cycle. It is interesting to observe here, how much more rapidly the mean effective pressures increase with ρ at a low compression ratio than a high one.

Fig. 9, showing the relationship between thermal efficiency and mean effective pressure is a most instructive diagram. It shows that :—

1. The higher the compression ratio the more is constant volume combustion at a disadvantage compared with variable volume combustion. Thus, at a compression ratio of 15, efficiencies for C.V. cycles having mean effective pressures greater than 60 lb. per square inch, are less than the efficiencies of V.V. cycles of the same mean effective pressures.

2. The efficiency of the D.C. cycle with $\rho = 1{\cdot}2$ is, for mean effective pressures above 60 lb. per square inch, always greater than the efficiency of the C.V. cycle.

3. The diminution in efficiency with mean effective pressure becomes less as the value of ρ in the D.C. cycle increases and, if the value of ρ is great enough, may even show an increase with increase of mean effective pressure, as appears in the figure in the cases when $\rho = 2$.

Fig. 10, which shows the relationship between efficiency and cut-off ratio, indicates at a glance that maximum efficiency in all cases is in the neighbourhood of $\rho = 1{\cdot}2$.

Fig. 11 is a diagram which is given here in the hope that, in conjunction with Figs. 6 to 10, it will prove serviceable to those engaged in the design and testing of internal-combustion engines. The assumption made in the construction of this diagram is, that 1 lb. of the working fluid occupies 18 cub. ft. at 373 deg. C. absolute, and 13 lb. per square inch, and it is further assumed that this is the state of the mixture at the beginning of compression in any hypothetical engine. Conditions certainly do not vary widely from this in normal cases working at full load. At the foot of the diagram the lines of quasi-hyperbolic shape and the straight lines radiation from the origin represent the adiabatic pressure-volume and general pressure-temperature relationships for the fluid under variable specific heat conditions. The intrinsic energy curve of the gas and the constant pressure energy line are both plotted against temperature.

Given the compression ratio and the heating value of the mixture to be used in the engine, it is possible to obtain from Fig. 11, with reasonable accuracy, the diagram to be expected in any hypothetical cycle which is being considered for purposes of engine design. Conversely, given the actual diagram from an engine, it is possible, by superposition of the diagram to the correct scale and in its correct position in Fig. 11, to determine readily the working temperature, &c., at any point in the cycle. The use of the diagram is best illustrated by describing specific examples.

The first example is illustrative of high-speed aero engines using petrol. It is assumed that the theoretically correct mixture strength, corresponding to a normal air/petrol ratio is equivalent to a heat supply of $0{\cdot}81 \times 10^6$ ft.-lb. per pound of cylinder contents. Following the lowest pv curve it is determined that when 1 lb. of gas is compressed from 18 cub. ft. to 4 cub. ft. (that is, a compression ratio of 4·5, common to air-cooled aero engines) the final pressure is 107·5 lb. per square inch absolute. Striking across horizontally from this to meet the radial p T line representing a volume of 4 cub. ft., it is found that the temperature on the scale given is 650 deg. absolute, corresponding to an intrinsic energy of $0{\cdot}15 \times 10^6$ ft.-lb. per pound. The total energy in the gas at the end of explosion will be, therefore, $0{\cdot}96 \times 10^6$ ft.-lb. per pound. Finding this point on the intrinsic energy line and striking vertically upwards to meet the same p T line as before, gives a maximum explosion pressure of 510 lb. per square inch absolute, assuming constant volume combustion. From Fig. 6 (page 648), this gives an indicated m.e.p. of 138 lb. per square inch absolute. Assuming the same m.e.p., but with variable volume combustion ($\rho' = 1{\cdot}2$), the maximum pressure, it appears from Fig. 6, would be only 415 lb. per square inch absolute.

The next example is taken from Mr. W. A. Tookey's paper read before this Institution in 1914. A particular gas engine was cited giving 87·5 lb. per square inch m.e.p., working with a final compression pressure of 135 lb. per square inch absolute, and a mixture strength of 40·55 British thermal units per cubic foot, or $0{\cdot}57 \times 10^6$ ft.-lb. per pound of cylinder contents. From the diagram of Fig. 11, it is readily determined that 18 cub. ft. of gas compressed from 14·7 lb. per square inch to 135 lb. per square inch absolute, occupy 3·33 cub. ft. This corresponds to a compression ratio of 5·4, which is the same as that obtained by Mr. Tookey, although in quite a different manner. The intrinsic energy of the mixture at the end of compression is determined in the same way as before to be $0{\cdot}16 \times 10^6$ ft.-lb. per pound, giving a total intrinsic energy of $0{\cdot}73 \times 10^6$ ft.-lb. per pound at the end of explosion. This further corresponds to an explosion pressure of 485 lb. per square inch absolute, and from Fig. 12 it appears that constant volume combustion to this extent should give 107 per square inch indicated m.e.p. The indicated m.e.p. of the engine, which was evidently in bad tune when Mr. Tookey first tested it, was subsequently raised to 96 lb. per square inch, a decided improvement over its original value, but not as good as would appear to be obtainable in a well-designed engine.

The pressure values and diagrams thus obtained from Fig. 11, can, of course, be derived much more quickly than the time taken to describe the method would appear to indicate, and the principles of its use in conjunction with Figs. 6 to 10 as described, are readily and easily mastered.

It is to be observed that mechanical efficiency is not included as a factor in the graphs given in Figs. 6 to 11, so that in arriving at brake thermal efficiency or brake m.e.p. it is necessary to take this into account.

6. *Regeneration.*—The raising of steam by means of the waste heat of an engine and utilising this steam in a high efficiency steam engine or turbine, is undoubtedly the best and most practicable method of increasing overall efficiencies. The schemes so far proposed or adopted, however, such as that typified by the recently-introduced Still engine, appear to suffer very much from an undesirable increase in the mechanical details of the engine structure.

Some recent work carried out at the Manchester College of Technology (which it is hoped will be published later) by a research student, R. Koivulehto, in conjunction with the writer, on the effect of water injection on the heat distribution in a gas engine cylinder has resulted in the determination of actual quantitative values relating to the amount of heat diverted from the jackets to the exhaust per pound of water injected per brake horse-power hour.

In connection with this, the following regenerative scheme is suggested, experimental figures being adduced in evidence of its value. The proposal is that by running a multi-cylinder engine on a maximum efficiency dual-combustion cycle of compression ratio 8 or 9 : 1 an indicated thermal efficiency of over 40 per cent is possible. By water injection a large proportion of the jacket heat would be diverted to exhaust, resulting, say, in an exhaust discharge of comparatively low temperature and containing 40 per cent. of the original heat contained in the fuel. Assuming 20 per cent. of this waste heat to be utilised in a high efficiency turbine of the Rateau type, the total overall efficiency would be raised to the neighbourhood of 50 per cent., and this without the introduction of any complicated steam-raising plant. The water injection also would serve to keep down the flame temperatures of the D.C. cycle.

Fig. 11.

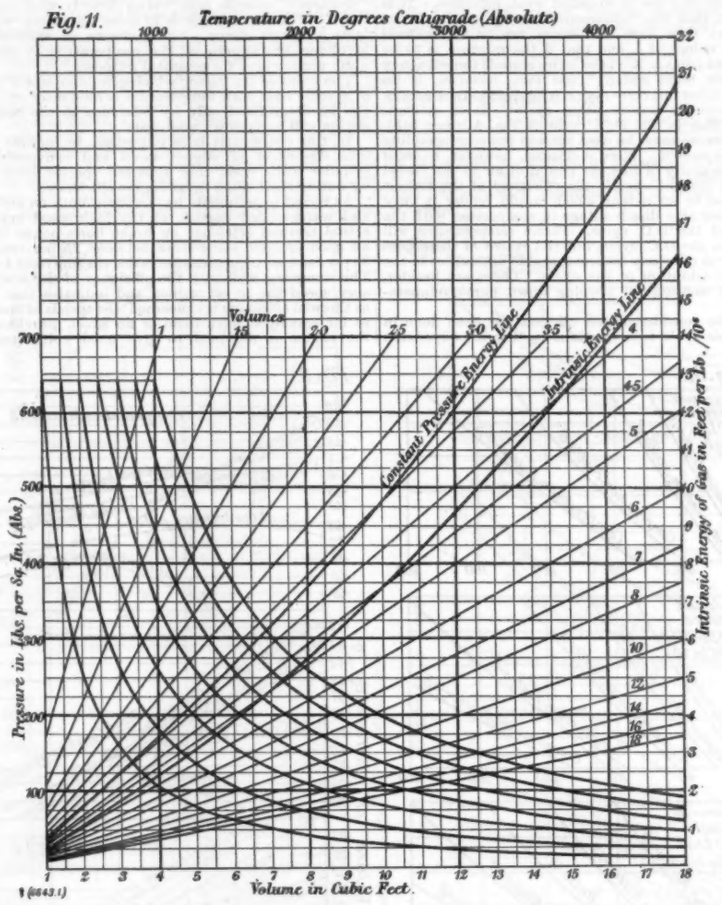
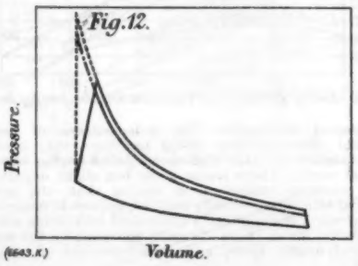


Fig. 12.



The following figures are typical of the results obtained in the above-mentioned water injection experiments :—

Pounds of water injected per brake horse-power hour ...	0	1·3
Exhaust gas temperature, deg. F.	722	646·0
Percentage exhaust heat ...	27	44·0
Percentage jacket heat ...	34	20·0
Brake horse-power per cent. ...	33	30·0

RADIOLOGY APPLIED TO THE TESTING OF MATERIALS.

By A. P. M. Fleming, C.B.E., M.Sc.(Tech.), M.I.E.E., and J. R. Clarke, M.Sc.

Introduction.—Throughout the history of engineering the testing of the materials of construction has always been a matter if utmost importance. Every improvement in quality has been eagerly seized by manufacturers and adapted to the refinement of design. Conversely, increasing knowledge of stresses and the competitive demand for materials having lesser bulks and improved strengths have imposed upon the suppliers of materials the adoption of every means to ensure improvement and uniformity of quality. Particularly marked has this been the case in such developments as those of the motor and aircraft industries, where great strength and lightness are predominant essentials of the materials used.

The means for ascertaining the soundness of engineering materials have never entirely kept pace with requirements. In the early days of the use of iron and steel, the safeguarding of quality depended upon visual examination of materials during their various stages of manufacture and application, coupled with a trust in the experience and knowledge of the workers associated with their production. At a later period testing appliances for determining physical characteristics were developed, and attention was also paid to chemical analysis. It has long been realised that these two means do not provide a complete knowledge of materials,

* Paper read before the Manchester Association of Engineers, on Saturday, December 11.

and afford little or no indication of internal physical defects. The use of the microscope for the examination of the structure of materials added a most useful instrument to the existing means of inspection and testing. All these methods, however, only afford a means of examination of some small portion of a consignment of materials or a part of a structure, and give no guarantee of the quality and uniformity of those parts not actually so examined.

The absence of means for detecting inherent flaws in materials that may be subjected to very considerable stresses, or for ascertaining the accuracy of assembly of complicated parts which are not susceptible of examination in the finished apparatus, has opened up a field for the application of X-rays to the examination of engineering materials and appliances. The use of X-rays in surgical work is well known, and it is not surprising that advance in the art of radiology has led to attempts to extend its scope in these directions. Such a means would appear from the first considerations to supply the one feature wanting to render the facilities for material testing complete.

The object of this paper is to consider to what extent radiology can be used to assist the engineer in testing materials, to indicate the limitations of the method as far as it has already progressed, and to suggest possible lines of advancement. The paper is not intended to add to the fundamental knowledge already gained by many prominent experimenters, but to present a general survey, having regard to the requirements of those who may desire to make practical use of this method of testing in works.

For the benefit of those who may have had no occasion to consider the subject, a considerable part of the paper has been devoted to an explanation of the production of the principal phenomena associated with X-rays.

2. *Visible and Invisible Rays.*—When radiations—such as those of light and heat—emitted from various substances and sources are under consideration, a familiar analogy has frequently been found in the water waves that are propagated when a stone is thrown into a pond. It is the modern view that all these radiations, the electric energy that is used in wireless telegraphy, the heat energy that comes from fire, light energy and all invisible rays which are, it is believed, of the same nature as light, are propagated as waves, the difference between them being a difference of wave length, which is measured, as with the water waves, by the distance between two successive crests. The following table shows the sequence of the radiations measured by their wave-lengths in millimetres.

TABLE I.

Nature of Radiation.	Wave-length in Millimetres.
Wireless telegraphy waves	15,000,000·000000000
Heat rays	0·005000000
Red light rays	0·000700000
Invisible light rays—	
Violet light rays ...	0·000400000
Soft X-rays	0·000000050
Hard X-rays	0·000000030
Gamma rays	0·000000010

The eye is sensitive to a comparatively small range of wave-lengths only, roughly from 0·0008 mm. to 0·00035 mm., that is to say, sensitive only to light rays and to no others, even though they are of the same nature. It has been found that substances that are quite opaque to heat and light rays are transparent to invisible light rays. Thus, a thin sheet of lead is opaque to heat and light but transparent to the invisible rays.

There is, however, a difference of degree also to be noted. For instance, a sheet of lead an inch thick will not transmit all the invisible rays but only those of very short wave-length. When, therefore, a substance is said to be opaque to a particular kind of radiation the question of thickness must be taken into consideration. All substances absorb all kinds of radiation to some extent It is the fact that different substances absorb X-rays to different degrees, that is the basis of the examination of materials by these rays. These invisible radiations, which penetrate opaque bodies, and whose presence after passing through them can be detected by the photographic plate, are derived from two sources, viz., certain radioactive materials, and electrical discharge through a gaseous medium.

Rays from Radioactive Substances.—Of the radioactive substances radium is that best known. It emits rays which, as regards penetrating power and certain other characteristics, are not homogeneous, but comprise three types. Of these types, alpha rays comprise small particles charged with positive electricity, that travel with a velocity of about one-tenth of that light, and have a very low penetrating power. Beta rays consisting of minute negatively-charged particles have a velocity of from five to ten times that of alpha rays and very many times the penetrating power. Gamma rays have a penetrating power of the order of 100 times that of the beta rays, and are believed not to consist of electrified particles but to the disturbances of the nature of light of exceedingly short wave-length. Each of these three types of rays comprise a range of differing degrees of penetrating power. The most penetrating rays of each type compare in this respect as follows :—*

	Penetrating Power in Air.
Alpha particles	7 cm.
Beta particles	250 cm.
X-rays are reduced to half intensity after penetrating about	10 m.
Gamma rays are reduced to half intensity after penetrating about	115 m.
Gamma rays reduced to 1/100th the intensity after penetrating about	760 m.

* Rutherford, "Radioactive Substances."

Rays Produced by Discharge through Gases.—Air is well known to be a poor conductor of electricity at atmospheric pressure. As the pressure is reduced, however, the electrical conductivity increases until a certain degree of rarefaction is reached beyond which the conductivity again diminishes. The relation between pressure and the electromotive force required to cause a discharge of electricity across an air space is shown by the graph in Fig. 1.*

The passage of electricity through a gaseous medium is accompanied by certain visible phenomena, which may be investigated by means of an electrical discharge tube arranged as shown in Fig. 2.

A simple form of this apparatus consists of a glass tube so arranged that it can be slowly evacuated, and have sealed into each end metal terminals A and B, between which a difference of electrical potential can be applied. The terminal A at which the electricity enters the tube is called the anode or anti-cathode, and the terminal B, where it leaves, the cathode.

When a sufficient difference of potential is applied to the terminals a spark passes between them, and as the tube is evacuated its interior becomes filled with a pinkish-coloured glow. If the pressure is still further reduced the glow gives place to a series of luminous striæ, and at a very high degree of rarefaction the cathode

Fig. 1. RELATION BETWEEN THE SPARK POTENTIAL & PRESSURE FOR AIR. SPARKING DISTANCE-1"/m

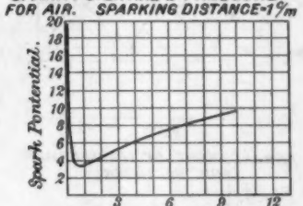
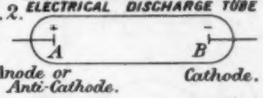
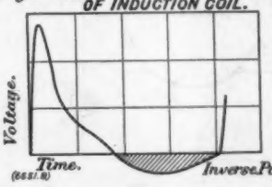


Fig. 2. ELECTRICAL DISCHARGE TUBE



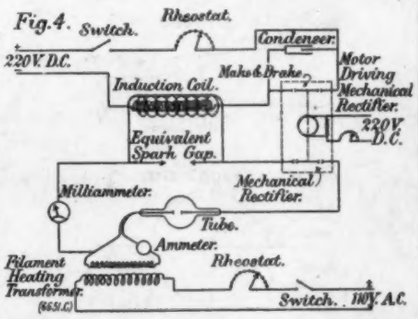
(665.A)

Fig. 3. SECONDARY VOLTAGE CURVE OF INDUCTION COIL.



(665.M)

Fig. 4.



(665.C)

is surrounded by a luminous glow beyond which is a dark region extending ultimately until it occupies the rest of the space in the tube. Where this dark space reaches the walls of the tube the glass shines with a brilliant fluorescence.

A solid substance interposed between the cathode and the fluorescent walls cast a sharply-defined shadow indicating the existence of radiations from the cathode. These radiations are known as cathode rays and consist of negatively charged particles termed electrons, their nature being independent of the residual gas in the tube. Where the rays strike the anode the heat developed by the impact may become so great as to cause platinum or even tungsten—which has a melting-point of 3,700 deg. C.—to melt. This is a most important consideration which will be dealt with later. Except for possessing a lower velocity cathode rays are identical with the beta rays already referred to.

In 1895 the German physicist Röntgen was working with an electric discharge tube which was evacuated to such a degree that the glass fluoresced. He was surprised to find that although the tube was completely enveloped in black paper a glass plate covered by potassium-platino-cyanide, which was on the table 3 m. away, became luminous. The paper precluded the possibility of either visible or ultraviolet light, which might have produced the luminosity, reaching the plate, so that there was evidently some new form of radiation emanating from the discharge tube. He found that a thick piece of metal cast a sharp shadow when placed between the tube and the plate, while pieces of wood and similar materials cast shadows which were much less dense, showing that the radiations which produced the luminosity could traverse to a certain extent bodies which are opaque to ordinary light. His further examination of this new radiation showed that it was propagated in straight lines and was not bent in passing from one medium to another. He found that the power of the radiation to penetrate a substance depended upon its density, so that, for example, if a hand was placed in the path of the rays, the bones cast a darker shadow on the screen than did the flesh. He traced the radiation to its source, which he found to be the region of the impact of the cathode rays on the walls of the tube. This form of radiation became known as X-rays or Röntgen rays.

* Carr. Proc. Roy. Soc., 1903, 21, 374.

X-rays resemble in all respects gamma rays except that the latter are far more penetrating. X-rays travel in straight lines in all directions from their source. Unlike cathode rays they are not diverted by the presence of the most powerful magnetic or electric fields, and in common with cathode rays they possess the power of exciting fluorescence, of affecting a photographic plate, and of making the air through which they pass conducting. Except that they are of very short wave-length they behave similarly to visible light rays.

Among the various other properties possessed by X-rays may be noted their therapeutic effects. While it is well known that X-rays possess certain curative properties the exposure of any part of the body directly to the rays may result in effects on the skin and underlying tissues producing so-called X-ray burns. Frequent and prolonged exposure may result in cancerous growths and even more serious effects. This necessitates the greatest care in the protection of the X-ray operator, and the methods adopted in practice for this purpose will be discussed later.

The penetrating power of X-rays depends upon their wave-length, the shorter the wave length the greater being the penetrating effects. Rays of shorter wave-length are termed "hard," to distinguish them from the less penetrating or "soft" rays of greater wave-length. The velocity and energy imparted to the electrons of the cathode rays increase with the potential difference applied to the terminals of the X-ray tube, and the energy of the X-rays produced when they strike an obstacle increases with the increase in voltage. It has been determined that the energy of X-rays is proportional to the fourth power of the velocity of the parent cathode ray, so that it is desirable to employ as high a voltage as possible to the X-ray tube provided that the heat generated by the impact of the cathode rays can be dissipated. This is a matter of importance since over 75 per cent. of the energy applied to the tube is converted into heat. Cathode rays are not all of the same velocity and X-rays may have different penetrating power even though the voltage used is constant. In the range of penetrating power there is usually one set of values that predominates, which is characteristic of the metal used for the anti-cathode. This predominating set of values increases practically in proportion to the atomic weight of the metal.

Secondary Rays.—When X-rays impinge on a substance secondary rays are produced, the most important of which are :—

Scattered rays.
Characteristic X-rays.
Beta-rays caused by the absorption of X-rays.

Scattered rays are of the same penetrating power as the original X-rays, but are distributed in all directions, mainly, however, in the same direction as the incident ray.

Characteristic X-rays are emitted when X-rays of sufficient penetrating power impinge on a metal surface. These rays are characteristic of the particular metal on which the ray falls.

In penetrating a substance X-rays become to some extent absorbed, and when the material is of considerable density, as, for instance, a metal, beta-rays are produced, having a velocity and penetrating power dependent on the original X-ray. The following table shows the extent of the penetration of materials of different densities by X-rays :—

TABLE II. *Showing the Extent of Absorption of "Medium" X-rays.**

Metal.	Density.	Intensity Reduced to One-half by a Thickness of Aluminium of : cm.
Aluminium ...	2·6	0·275
Iron	7·7	0·012
Copper	8·9	0·0096
Zinc	7·2	0·011
Silver	10·5	0·0037
Tin	7·3	0·0054
Platinum ...	21·5	0·0015
Gold	19·3	0·0014
Mercury	14·4	0·0022
Lead	11·35	0·0028

X-ray Examination of Materials.—In the photographic examination of substances by X-rays the photographic plate or film is placed immediately behind the object of examination through which the X-rays pass. There may be interposed between the photographic plate and the object under examination an intensifying screen prepared from calcium tungstate. This intensifying screen becomes luminous and adds to the results produced by those rays acting directly on the silver bromide on the photographic plate, and by this means the time

* Janus and Reppchen, Trans. Faraday Society, 1919, 15, 2.

of exposure can be shortened. It must be remembered that the results obtained on the photographic plate or by a fluorescent screen represent merely a shadow picture of the object interposed in the direct line of the X-rays. The detail in the picture depends on the difference in the density of the parts traversed by the rays, and where the object varies in thickness or in density the corresponding differences will be noted on the plate. The sharpness of definition, however, depends very largely on the extent to which the plate can be protected from the effect of secondary rays.

It will be appreciated that the shadow picture shown by X-rays will not necessarily indicate the counterpart of what would be visible if sections of the object could be viewed in different planes, and some experience is necessary before these shadow pictures can be fully interpreted.

3. *Production of X-rays.*—The production of X-rays involves the following apparatus :—

(*a*) Means for obtaining high voltage and rectification whereby the flow of current to the X-ray tube is unidirectional.

(*b*) The X-ray tube.

Production of High Voltages.—Three methods may be considered, viz. :—

(*a*) Influence machines.
(*b*) Induction coils.
(*c*) Transformers.

Influence Machines.—This apparatus is the only means at present practicable for supplying high voltage continuous current, although alternatively it might be possible to employ a very great number of accumulative cells connected in series. Influence machines are unreliable, particularly in damp climates, and as at present constructed are hardly likely to be practicable for X-ray work.

Induction Coils.—The induction coil consists of two concentric windings insulated from each other surrounding a laminated iron core. One winding, called the primary, consists of comparatively few turns ; the other, commonly known as the secondary, of a large number of very much finer wire. Voltage is supplied to the primary winding from a direct current source through an interrupting device, which causes the primary circuit to be completed and broken very rapidly. As a result of the intermittent magnetic field thus set up a voltage is induced in a secondary winding of an amount determined by the number of secondary turns it contains. An interrupter connected with the secondary winding breaks that circuit each time the primary circuit is closed. The terminals of the secondary winding are connected to the X-ray tube, and by this arrangement unidirectional current is caused to flow through the tube. The current, however, is not uniform but fluctuates according to the graph shown in Fig. 3.

It is important to note that some interrupting means is necessary in the secondary circuit, otherwise an inverse current may occur which will cause cathode rays to be sent from the anti-cathode, and increase the blurring of the shadow picture of the object examined and also risk spoiling the tube. Fig. 4 shows a diagram for connections of an induction coil arranged for X-ray work.

Various methods of interrupting the primary circuit have been employed, but the most common is that of rotating contacts in a mercury bath, or a system of rotating mercury jets impinging on fixed metal plates. The device for ensuring a unidirectional current in the secondary circuit may be electrical or mechanical. The simplest form consists of a point and plate spark gap, whose operation depends on the fact that a spark passes more readily when the point is positively charged than when it is negatively charged. This arrangement, however, is not suitable when large currents are employed, and it has been replaced by other types of valve. A more satisfactory device is the Lodge valve tube, which consists of a spiral of aluminium wire connected to the negative terminal and a positive terminal of iron wire, the whole being mounted in a highly-exhausted bulb, In the most modern forms of valves the underlying principle is the emission of ions, i.e., electrically charged particles, by incandescent solids. In a tube evacuated to such a degree that the applied electromotive force does not produce any discharge between the electrodes, the heating of one electrode to incandescence will enable the current to pass in the direction which causes the heated electrode to be the cathode. Up to the present such valves have not been made to take the high voltages used in industrial radiography, and mechanical methods are employed to prevent the inverse current from reaching the tube. An example of this method is the device already mentioned for breaking the secondary circuit of an induction coil.

Transformers.—A transformer is similar to an induction coil except that a closed magnetic circuit is used and the windings may be differently arranged and insulated. Alternating current is supplied to the primary winding, and the ratio between this and the voltage induced in the secondary is the same as between the primary and secondary turns. To obtain a unidirectional current in the secondary circuit means must be taken to prevent the ordinary reversal of current at the end of every half-wave. This is done by a commutator device consisting of a circular insulating disc around which are equally spaced four contacts. The disc is rotated at a speed which synchronises with the alternations of current, and by means of contacts placed near the edge of the rotating disc the rotation of the flow of current is reversed at each half-period. The wave shape applied to the primary will be practically sinusoidal, as shown in Fig. 5, and that supplied by the secondary circuit to the X-ray tube will be rectified as shown by the dotted portion. Sometimes part of the wave is cut out, as shown in Fig. 5*a*. The portion eliminated does not contribute to the production of X-rays but only heats the tube. The arrangement of the transformer is shown in Fig. 6.

Both induction coils and transformers are extensively used for X-ray work. Certain definite advantages are possessed by both types of apparatus. The induction coil is comparatively convenient to handle and set up, and it is claimed by many investigators that the peaked wave shape of the induction coil offers an advantage over the sinusoidal shaped wave obtained by the transformer. There is considerable divergence of opinion on this point. In other directions, however, there is some advantage in the use of a transformer in that it enables higher voltages to be obtained than with the induction coil, and can be readily adapted, due to the greater facility by which the windings can be insulated. Hence for the highest voltage work it is probable that transformers will be most generally used. At the present

Fig.5. PRIMARY VOLTAGE WAVE SHAPE.

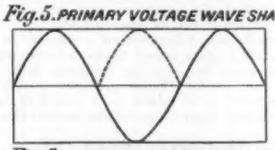
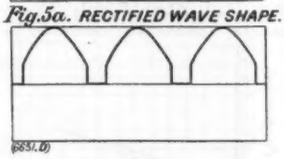


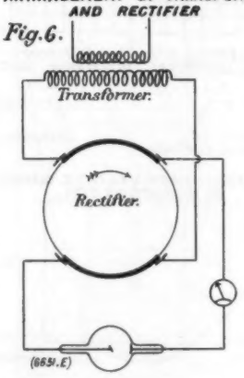
Fig.5a. RECTIFIED WAVE SHAPE.



(6651.D)

ARRANGEMENT OF TRANSFORMER AND RECTIFIER

Fig.6.



(6651.E)

Fig.7. RÖNTGEN TUBE.

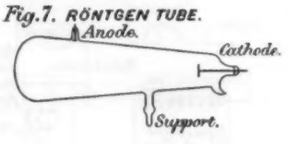
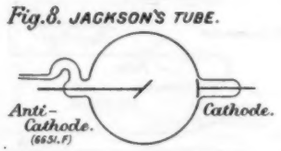
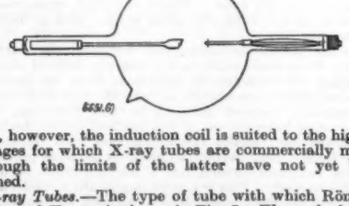


Fig.8. JACKSON'S TUBE.



(6651.F)

Fig.9. COOLIDGE TUBE



6651.G)

time, however, the induction coil is suited to the highest voltages for which X-ray tubes are commercially made, although the limits of the latter have not yet been reached.

X-ray Tubes.—The type of tube with which Röntgen discovered X-rays is shown in Fig. 7. The cathode was a flat disc, and the anode was mounted in a small side tube. The cathode rays, striking the large end of the tube, produced fluorescence and also gave rise to X-rays. As the area from which the X-rays were emitted was large, the shadowgraph which was produced by the interposition of a body between the disc and screen was blurred and indistinct. Campbell Swinton, in 1896, modified Röntgen's tube by allowing the cathode rays to fall on a sheet of platinum, and in this way obtained considerable improvement in the definition of the shadowgraphs. The next development was by H. Jackson, who used a concave cathode to focus the rays (an invention of Crookes in 1874) and mounted the platinum target at an angle of 45 deg. to the rays. Jackson's tube is shown in Fig. 8, and the same principle is still employed in nearly all X-ray tubes. The tube has been slightly modified, however, though not in the essential arrangement of the cathode and anode. In 1896, Gunderlach introduced an auxiliary anode, and this will be found in most modern tubes of this type. Its purpose is to steady the discharge, although its mode of action is not quite clear. The cathode is usually made of aluminium and is mounted just within the neck of a side tube. The anti-cathode, which is inclined at 45 deg. to the cathode rays, is and has been the subject of much investigation.

It has already been noted that an enormous amount of heat is developed when the cathode rays impinge on the anti-cathode, and the rapid removal of this heat is essential. For this reason, the metal of which it is made must have a high thermal conductivity ; sometimes it is water-cooled. The production of heat, however, is so great that the temperature of the anti-cathode always rises considerably, and thus it must be made of a metal of high melting-point, such as platinum or tungsten. These metals also satisfy the first requirement, and in addition have a high atomic weight. Jackson's tube has been modified in another manner by the addition of a device for "softening" the tube, i.e., reducing the degree of vacuum. This is necessary, because the pressure of the gas inside the tube decreases when worked for a long period.

The Coolidge Tube.—Prior to 1913, X-ray tubes were constructed so that a small amount of residual gas was left in the tube. When an e.m.f. was applied to the tube, the few ions existing in this residual gas developed such a velocity that they were able to ionise the gas molecules and so render the tube conducting. In 1913 Dr. Coolidge designed a tube which was fundamentally different from this. The pressure of the residual gas was reduced to such a low value that no current could be passed through it, however great the applied e.m.f. The electrons to carry the current and form the cathode rays were supplied by a spiral of tungsten wire which was heated by a subsidiary current. The advantages of such a tube are so great that it has almost completely displaced the "gas-tube" in X-ray practice. It should be mentioned that, almost simultaneously, Lilienfeld designed a tube in which the electrons were similarly supplied. It differed in other respects and was largely used in Germany during the war. At present, however, Coolidge tubes are being made in this country, and it would appear that they have supplanted those made to the design of Lilienfeld.

In such tubes the vacuum is about 1,000 times that in an ordinary X-ray tube, and remains constant even when run for many hours. The intensity of the rays is easily controlled, independently of the penetrating power, by varying the temperature of the cathode. The penetrating power is changed as in an ordinary tube by regulating the applied e.m.f., but this does not involve a change in the intensity as was formerly the case. The origin of the cathode rays renders it easier to focus them on the anti-cathode, and the focal spot does not wander or broaden as with the gas-tube. Using a tube with a water-cooled anti-cathode, Coolidge was able to produce X-rays for 68 hours continuously at 100 milliamps and 70 kilovolts. Other tubes have been run with an input of 14 kilovolts as compared with the 5 kilovolts which could be intermittently put into a gas tube.

It might be thought that the Coolidge tube would act as its own valve and be self-rectifying ; the temperature of the focal spot of the anti-cathode, however, causes it to emit electrons when an inverse e.m.f. is applied. Nevertheless, a self-rectifying tube to work with a pressure of 70 kilovolts has been designed, and it is hoped to improve on this with a self-rectifying tube, but only about 8 in. long, to work under oil. The development of the Coolidge tube was fully described by the inventor in a paper read before the Röntgen Society, in July, 1920. The standard Coolidge tube is shown in Fig. 9.

(*To be continued.*)

Hardening Concrete.—Experiments by the United States Bureau of Standards to develop a method of accelerating the hardening of concrete, especially when it is to be used in wet or damp situations, have shown says *Power User*, Toronto, that 4 per cent. of calcium chloride added to the mixing water increases the strength of concrete at the age of one day 100 per cent. or more. In some cases, in two days the strength equalled 75 per cent. or more of that normally attained in one month.

The Institution of Civil Engineers—Birmingham and District Association.—The first local association of the Institution of Civil Engineers to be inaugurated is that of Birmingham and District, the first local president, being Mr. J. D. Watson, engineer to the Birmingham, Tame and Rea Drainage Board. The Association of Birmingham Students of the Institution was formed in 1884, and this body is now incorporated in the new local association. The new body, of which Mr. H. V. Overfield, B.Sc., and Mr. E. E. Jeavons are joint hon. secretaries, will, it is hoped, offer to the class of corporate members officially known as "non-resident," many of the advantages hitherto enjoyed by "residents" only. The fact that the discussion of papers, and the other advantages centralised in the Institution in its Westminster home have been only available to comparatively few members, has been rather keenly felt by many unable to pay visits to London, and the change of policy will undoubtedly be welcome, and in time extended to other centres in the country.